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THE CHAIN SUSPENSION BRIDGE AT BUDAPEST, HUNGARY.

In the heated discussion which followed the publication late in 1903 of plans for a chain cable suspension bridge across the East River at New York City, comparative reference was repeatedly made to the new chain cable bridge then just completed at Budapest, Hungary. There is no possibility now that the original plans for the East River bridge will be carried out, but the fact that these plans were prepared and approved by engineers of high standing in the face of a vigorous opposition, make a description of their most notable precedent of general interest. The Budapest bridge merits, moreover, because of its unusual construction and its great size, a careful description independently of any special interest it may have in connection with the controversy that has just been mentioned. We have, therefore, secured from correspondents abroad illustrations and notes of the construction and methods of erection, and from these have compiled the following account of those features of the bridge which are of most interest to American engineers.

VIEW OF BUDAPEST AND THE RIVER DANUBE, SHOWING NEW SUSPENSION BRIDGE ON THE LEFT, AND OLD FRANCIS JOSEPH CANTILEVER BRIDGE ON THE RIGHT.

DESCRIPTION OF STRUCTURE.

The Budapest chain cable suspension bridge crosses the River Danube at a point which brings its Pest end a little below the heights on which stands the Royal Palace. This location is at the narrowest point of the river within the city limits. The general appearance of the bridge is shown in our front-page picture and by the large general view Fig. 1. Referring for a moment to the front-page picture, it needs to be noted that the combination of several photographs joined together and rephotographed to get the view shown exaggerate the curve of the bend of the river between the two bridges; this bend is really a very flat curve. It may be noted also that the bridge on the right hand is the famous Francis Joseph cantilever bridge. The diagram elevation and plan of Fig. 2 show clearly the main dimensions and the general structural elements of the new suspension bridge.

The bridge consists of a center span 290 m. (951.2 ft.) long, and two side spans each 44.3 m. (145.3 ft.) long. The main span is a suspension span carried by four chain cables hung from steel towers on masonry pedestals. Four shore chains or back stays connect each tower back to the masonry anchorages on the opposite banks of the river. The stiffening trusses are two in number and are continuous from anchorage to anchorage. Their shore ends are anchored down. Throughout the center span the stiffening trusses are suspended from the cables, but the shore span portions act as girders. The total length of each truss is 1,241.8 ft. The bridge was built under the direction of Chief Engineer Aurel Czekelius, Department of Bridges, Hungarian Ministry of Commerce. It was christened the Elizabeth Bridge.

SUBSTRUCTURE—The substructure of the bridge comprises two tower pedestals of masonry and two masonry anchorages. The tower pedestals call for brief mention only, they being plain masonry piers founded on pneumatic caissons. They are high enough to bring the bolster pins on which the tower legs rest, 10 m. (32.8 ft.) above mean water level.

The anchorages were necessarily of more complicated construction, as shown by the drawings of Figs. 3, 4 and 5. As shown, each anchorage consists of a footing of concrete on which was erected ashlar masonry laid in cement mortar and with all exposed faces of cut stone. In the concrete footing there was introduced a damp-proof layer of asphaltium, which is mentioned here because it was the partial cause of a movement of the right hand anchorage after the bridge was nearly completed. During construction hot springs were encountered boiling up through the fissures of the rock foundation bed. These were sealed by the concrete footing, but the heat penetrating the concrete softened the damp-proof course so that the superincumbent masonry moved slightly forward under the pull of the chains. A hole was cut through the masonry to the spring, the water was forced back by air pressure and the rock crevice was filled with concrete. In addition a large mass of concrete was deposited in front of the toe of the anchorage, as shown by Fig. 3.

The manner of anchoring the back stay chains to the masonry is indicated by Fig. 3 and the connection is shown more in detail by the sections in elevation and plan of Figs. 4 and 5. As will be seen, the terminal links of each chain pass through a yoke which bears against two cast steel pedestals set on opposite sides of the chain gallery. The pull exerted on the anchorage by each pair of chains is 3,300 metric tons.

CHAIN CABLES.—The suspension cables and back stays are chains composed of links of eye-bars connected by pins. There are four of these chains, two on each side of the bridge and set one above the other and parallel in vertical profile from the point marked b in Fig. 3 to the corresponding point in the opposite anchorage. As will be seen from the elevations Figs. 2 and 3 the links of the two chains break joints so that the suspenders may be hung alternately from the upper and the lower chain. The two chains of each pair are substantially alike, except for some variations in the link lengths. Generally the links consist of 19 and 20 eye-bars alternately and neglecting a few special links at the tower connections the link lengths increase from center of main span to tower and from anchorage to tower. Table I shows the exact composition of the upper chain. A noteworthy feature of the eye-bars is that they are machined to shape from rolled

TABLE I.—Showing Composition of Links of Cable Chains.

Links.	Length. Meters.	No. Eye-bars.	Depth. Mm.	Thickness. Mm.	Drain of Pins. Millimeters.
1— 2..	5.839	19	530	25	330
2— 3..	9.275	20	500	25	330
3— 4..	6.564	19	490	25	320
4— 5..	9.815	20	482	25	320
5— 6..	10.49	21	475	25	320
6— 7..	10.558	22	460	25	320
7— 8..	10.621	22	460	25	320
8— 9..	10.689	22	455	25	320
9—10..	8.237	22	455	25	320
10—11..	3.197	20	455	25	320
11—12..	2.488	18	455	25	320
12—13..	6.131	20	455	25	320
13—15..	12.766	20	440	25	310
15—17..	12.685	20	431	25	310
17—19..	12.505	20	430	25	320
19—21..	12.398	20	430	25	310
21—23..	11.793	19	420	25	310
23—25..	11.510	20	420	25	270
25—27..	11.151	19	410	25	270
27—29..	10.267	20	410	25	270
29—31..	10.057	19	410	25	260
31—33..	10.030	20	410	25	260
33—35..	10.011	19	400	25	260
35—37..	9.999	20	400	25	260
37—38..	4.348	19	400	25	260

FIG. 1. CHAIN CABLE SUSPENSION BRIDGE AT BUDAPEST, HUNGARY.

plates and not forged as is usual in America. The link pins also vary from the eye-bar pins commonly used in America as will be seen from the drawings of Fig. 6. At the towers the two chains connect with separate pins rigidly fixed to the tower framework.

SUSPENDERS.—The suspenders which connect the stiffening trusses to the chains are hung alternately from the upper and the lower chains and from the regular chain pins. Their construction and connections are shown by Figs. 7 and 8. Each suspender consists of two channels riveted to eye-plates which slip over the chain pin. At their lower ends the channels are riveted to yokes having two eyes through which pass bolts. These bolts at their lower ends pass through other yokes riveted to a diaphragm in the vertical member of the truss. These several parts and their relation to each other may be readily traced out on the drawings of Figs. 7 and 8.

TOWERS.—The towers which carry the chain cables are of steel framework construction and of the general form shown by the drawings of Figs. 3 and 9. Each tower consists of two legs set on opposite sides of the bridge and connected together across the bridge by two cross girders and portal bracing worked out in an ornamental style. Each tower leg consists of four posts, two inside and two outside posts. At the bottom the two inside posts are brought together and connected to form a single member by means of diaphragms and a cast bolster. The two outside posts are similarly coupled together. At the top all four legs are brought together and connected so as to form a single member to carry the cable chain pins.

Turning now to the details of the tower construction, the only parts that call for particular mention are the bottom and the top sections. The general details of the bottom section of one pair of posts are shown by Fig. 10. It will be noticed that the main post members carry an extraneous framework of light steel members; the purpose of this is to support the cast plates which give the tower its ornamental appearance as shown in the accompanying photograph views. The main points to be noticed are the pin bearings of the tower legs, which permit the towers to swing forward and backward under the pull of the cables if the necessity for such movement should occur during construction; afterwards no mo is expected.

The tower construction at the top is sh Fig. 11. The principal points to be noted spacing links between the tower and the and the sliding bearing for the upper cha The bending together of the tower legs to single member is also clearly shown. Some principal dimensions of the tower are:

Height of tower pedestal pins	
Height of upper chain pin	
Height of lower chain pin	
Height of pedestal pin to upper chain pin	
Height of top of tower	
Height of upper chain at mid-span	
Height of lower chain at mid-span	
Deflection of chains	

TRUSSES AND ROADWAY.—The brid two stiffening trusses anchored at the anch and supported by a rocking post at each The trusses are spaced 20 m. (65.6 ft.) apart c., and are 6.985 m (22.97 ft.) deep at th and 4.75 m. (14.58 ft.) deep at mid-span m. (13.08 ft.) at the anchorage ends. For tance of 100 m. (328 ft.) at the center of the the top and bottom chords of the trusses are allel. The roadway platform has the same gitudinal profile as the top chord and is below it. The space between trusses is divided into a central roadway 11 m. (35.1 ft.) wide and two sidewalks, each 3.5 m. (11.48 ft.) wide over the main span and 3.7 m. wide over the shore spans. The roadway construction is clearly indicated by the cross-section of Fig. 2 and the detail shown in Fig. 8.

The portions of the stiffening trusses that are of most interest are the anchorage ends and the pier supports. The latter are shown in detail by Fig. 12. As will be seen the stiffening trusses pass between the pairs of posts of each four-post tower and are hung from pins at the upper ends of two posts the lower ends of which are hinged by pins to diaphragms connecting the tower legs. The details of this arrangement are clearly shown by the drawings of Fig. 12. This pier support permits free dilatation of the trusses due to temperature changes, etc. It is also to be noted here that the suspenders to the floor girders at mid-span are rigidly connected, so that the expansion takes place from this rigid connection toward each anchorage.

The details of the anchorage ends of the shore spans are shown by the drawings of Figs. 13 and 14. As shown by Figs. 2 and 3 a vertical post is pivoted to the end pin of the bottom chord of each truss and extends down a well in the anchorage masonry to an anchor taking bearing against the roof of an anchor chamber. The details of this anchor construction are shown by Fig. 13. Fig. 14 is a diagram of the wind bracing at the end of the span, and Fig. 15 is a detail of the construction at the point A of Fig. 14. As will be seen the wind bracing terminated at span ends in cross-beams which have a sliding bearing between guides in the abutment masonry.

LOADS AND STRESSES.—The assumed loads

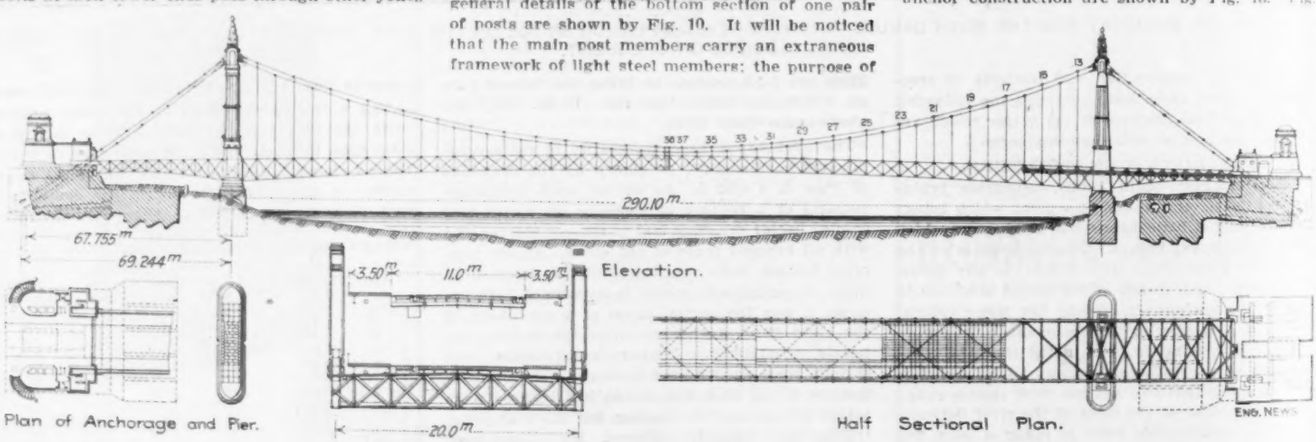


FIG. 2. DIAGRAM ELEVATION AND PLANS OF BUDAPEST SUSPENSION BRIDGE.

and allowable stresses employed in dimensioning the various parts of the bridge. For the floor system and suspenders, two four wheeled 16-ton cars set side by side on 1.5 m. tracks and having a wheel base of 3 m., or a uniform load of 450 kgs. per sq. m. were assumed. For the promenade

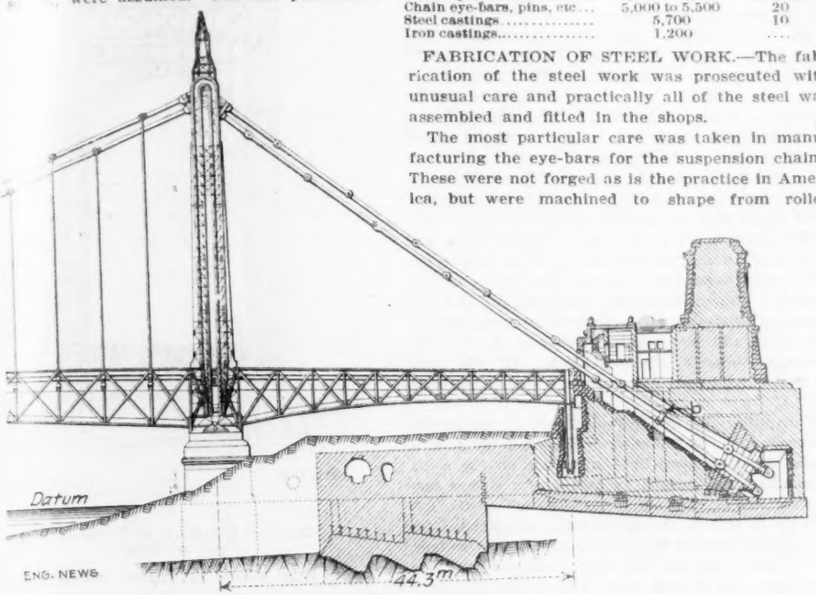


FIG. 3. SECTIONAL ELEVATION SHOWING GENERAL ARRANGEMENT OF ANCHORAGE FOR CHAINS AND END SPANS.

floors, the stiffening girders, the chains and the portals a uniform load of 450 kgs. per sq. m. of road surface was assumed. For wind pressure 250 kgs. per sq. m. was assumed for the bridge unloaded and 150 kgs. for the bridge loaded. The maximum allowable unit stresses were:

	Kgs. per sq. cm.
Floor members and suspenders	850
Stiffening trusses	1,100
Towers and wind bracing	1,200
Shear on rivets	750
Bearing on rivets and bolts	1,800
Chain eye-bars, tension	1,400
" " shear	850
Bearing on pins	2,200
Bending strain on piers, etc	1,500
" " steel castings	1,400
" " iron "	800

MATERIALS AND FABRICATION.

The material used for the metallic structure of the bridge was steel, except for certain castings. In general rolled or forged steel was used for the chains, trusses and towers, for the rocker posts in the towers and for all pins and adjusting keys; steel castings were used for pedestal anchorage imposts, nuts of all visible pins, truss anchors and other minor parts; and cast iron was used for the pedestal bed plates, for the imposts of the truss anchorages and for minor members. Altogether the metal used amounted to 11,169 metric tons, or about 12,285 tons of 2,000 lbs. This material was all furnished by the iron works of the State; the steel coming from the works at Diosgyör, the iron castings from the works at Zolyombrézo and the pig iron from the blast furnaces at Vadjahanyad.

QUALITY OF METAL.—The quality of the various materials as determined by tests was as follows:

	Tension, kgs. sq. cm.	Elongation, p.c. in 20 cm.
Structural steel	3,500 to 4,500	28 to 22
Rivet steel	3,500 to 4,500	32 to 26
Buckle-plate steel	3,500 to 4,000	26 to 22
Chain eye-bars, pins, etc	5,000 to 5,500	20
Steel castings	5,700	10
Iron castings	1,200	....

FABRICATION OF STEEL WORK.—The fabrication of the steel work was prosecuted with unusual care and practically all of the steel was assembled and fitted in the shops.

The most particular care was taken in manufacturing the eye-bars for the suspension chains. These were not forged as is the practice in America, but were machined to shape from rolled plates. The specifications required that the plates should be rolled to exact gage, 25 mm., and should be perfectly flat and true in all directions. To minimize chances of variation from temperature changes it was required that all templates, gages and scales should be made of the same material as were the eye-bars. In the final boring of the eye-bars it was specified that all the bars for each link should be assembled and bored at one operation. The maximum allowable deviations from the prescribed dimensions were as follows: Length of bar c. to c. of pin holes at 10° C, 3 mm.; diameter of pins 0.5 mm.; diameter of pin holes 1 mm. greater than diameter of pins; half-length of chain center of tower pin to center of main span 40 mm.

The eye-bars were manufactured at the works at Diosgyör. The rolled plates were first set between two machines which milled out four semi-

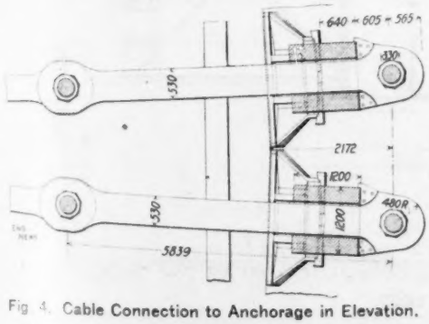


Fig. 4. Cable Connection to Anchorage in Elevation.

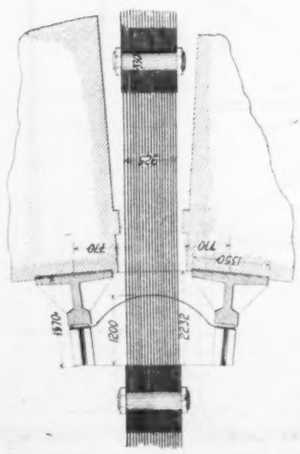


Fig. 5. Cable Connection to Anchorage in Plan.

circles in the edges to form the necks of the bar. They were then transferred to machines which bored the pin holes roughly to gage and milled the ends of the plates to the circular form of the head. The next operation was to plane the edges of the plate to remove the surplus metal between necks and thus form the body of the bar. When all the bars for two chain links had been completed as described they were assembled as they would be in the chains, firmly bound together, and the roughly bored holes were rebored to exact size. The total number of eye-bars in the four chains

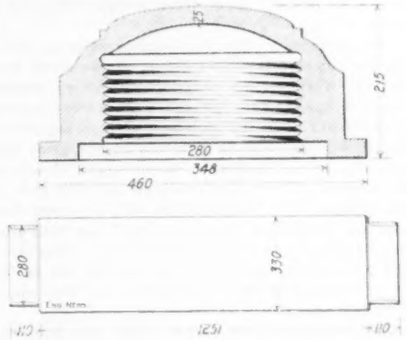


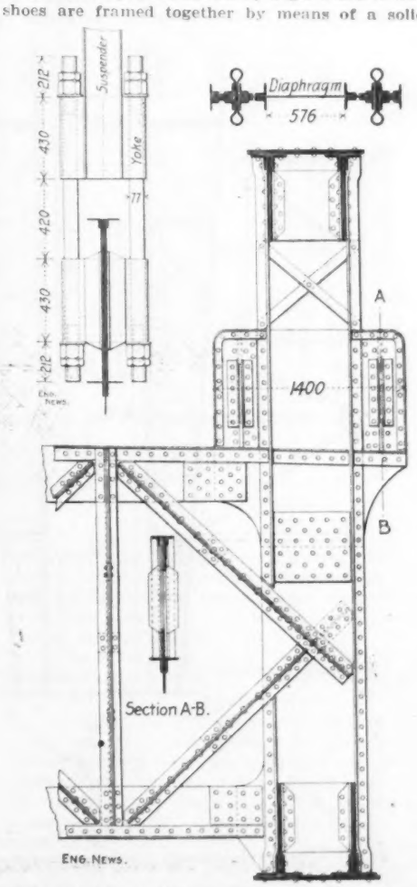
Fig. 6. Details of Pin and Nut for Chain Cables.

is 4,094, and the time required for their manufacture was from March 21, 1899, to Dec. 22, 1900, or 21 months.

CONSTRUCTION AND ERECTION.

Construction was begun on the foundations for the anchorages and piers in 1897 and the placing of the metal began two years later. The first metal work was the placing of the anchors and the tower links of the back stays.

The anchor beams, their regulating wedges and the shoes or imposts of steel castings, which weigh 6,700 kgs., are shown by Figs. 4 and 5. The shoes are framed together by means of a solid



Figs. 7 and 8. Details of Suspender Connection to Stiffening Truss.

framework of I-sections and the whole was (July, 1899,) set upon very carefully alined and then underpinned by timbers and beams until such later time as the equipoise of the main chains would relieve the underpinning struts.

Chain erection proceeded continuously up to the

level of the upper chords of the shore spans, and was thereafter stopped for a period of some months to allow work to be pushed on with the bridge proper and for the erection of the tower and chain falseworks. The chain ends (December, 1899,) were wrapped up with waterproof materials to protect them from weather deteriorations.

Simultaneously with the progress made in erecting the tower falseworks (33 m. above mean water) the work on the cantilever or shore trusses was also much advanced, the trusses resting then (May, 1900,) upon the pier-heads, there supported on oak wedges; and by June the rocker arms had been pinned to the gussets in the upper chords of the trusses. The tower pedestals on each side of the trusses, and which weigh 15¼ m. tons, had been set in position during the previous year and all was now ready for the tower-posts. This erection followed a week later, and connection of the lower bearings of the rocker arms was then made with the posts.

The junction of the rocker arms was not rendered operative until a much later period when the main suspension chains had been connected at bridge middle and the wooden struts supporting the upper halves of the tower pedestals had been removed. In the meantime the expansion and contraction of the structure under temparature influences proceeded, shorewards and riverwards, from this point of fixed support upon the piers.

By this time (July, 1900,) the heavy falseworks for the anchorage chain erection had been extended back as far as the chain eyes 4 and 5, work was then recommenced and pushed on rapidly upon the falseworks named, reaching by the third week in September the point of advance (45 m. above water level). When at the height of 43 m., to obviate the danger of the towers tilting in the wind, a number of consolidations were made, first at the height of 25 m. above mean water and at panel points 9 and 13, and then at + 30 m. and at points 8 and 13, the towers being stayed at the various stagings by means of timber struts and keys. With these stiffenings and braces erected in advance it was possible to adjust the towers with great accuracy in the axis of the bridge and for the exact centering of the chains. As the work proceeded the traveling cranes were raised from stage to stage in advance of the metallic construction.

The tower-head suspension bolts are hollow and each 500 mm. external diameter. They are carried in the tower-heads by two outside webs or reinforced sides having a total thickness of 127 mm., and one central web or diaphragm consisting of the united inside plates of the two posts heavily reinforced to a thickness of 228 mm. All these reinforcement plates, about 6 m. in length, were reassembled in the field by means of tightly-driven bolts. Subsequently, after the whole of the work had been permanently riveted up, the tower suspension bolt-holes were bored out to the full size required. The upper oblong openings for the bolt bearings came together exactly as prepared in the shops and only required polishing up on their lower seatings for the bolt-block. All this work in the tower-heads was completed early in April, 1901.

The piling for the falseworks was, during the severe winter of the same year (1900-1901), protected from damage by floating ice on the swift current of the Danube by means of a strong system of icebreakers. After the passage of the ice, middle of March, the pile-driving commenced for the trestle piers to support the temporary bridges. Two steam pile drivers were employed, and the ultimate cost of this work was 18,000 Kronen.

The temporary bridges were assembled on erecting stages on the quays and towed into position by means of floating stagings of steel, built upon four pontoons and decked over with a platform interchangeable between all the four openings allowed between the trestle piers. The parabolic-chord temporary trusses for the same span are, so far, not mounted in place. When this last pair of temporary bridges was erected, the floating stagings were, of course, withdrawn completely.

Fig. 9. Diagram Elevation of Tower in Transverse Plane of Bridge.

These temporary bridges were of 51 m. length, the clear way between the four channel openings being 48 m. Their width was 11.6 m. Parabolic trusses were employed for the two middle openings for the sake of greater lightness. The temporary bridges were eight in number—two to each opening—and built, along with the other work, at the Budapest bridge shops of the Hungarian State Railways. The total weight of chains and members to be supported by them was calculated as equivalent, approximately, to the dead load to be supported by ordinary-type over-street bridges —that is, a test load of two-axled wagons having

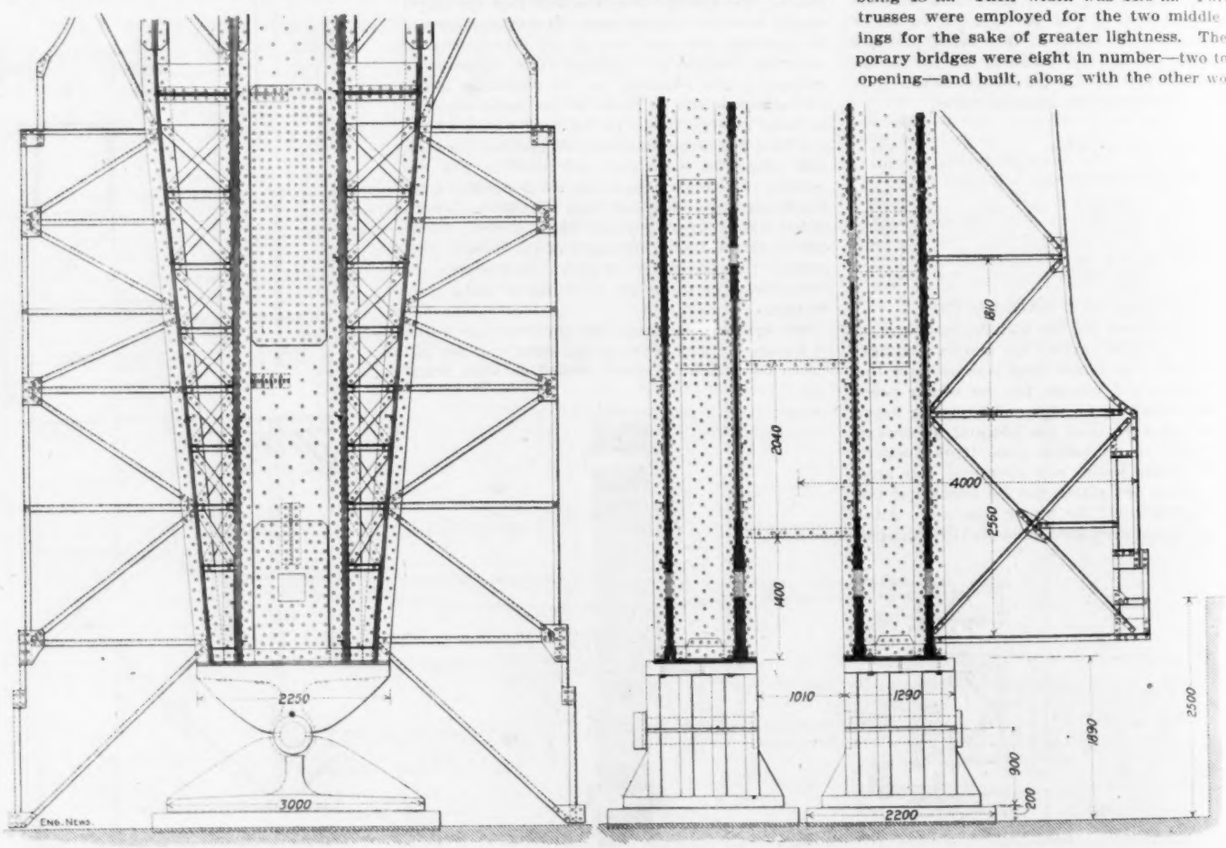


FIG. 10. DETAILS OF BOTTOM SECTION OF TOWER LEGS.

a pressu… 4,000 kgs. below each wheel and representing uniformly distributed load of 400 kgs. per squ… meter of road surface.

The f… g stages, by which they were mounted, effe… an economy in the time required for their e… n on the temporary pairs. The stagings or fram… ks, four in number and carried upon pontoon… m. in depth, had each a width of 5½ m. (equ… therefore in aggregate to nearly one-half the … gth of the openings between piers), and a leng… f 32 m.—consequently long enough to permit … simultaneous erection of two bridges alongsi… The frameworks of all the stagings were c… cted and braced together beneath the overlyi… platform. Each 11½ m. wide temporary br… was mounted apart 20 m. c. to c. (the width … rt of the chains, c. to c.) with an interval of 8½ m. between the centers of their inside girders. The bracing connections between the various stagings were secured with bolts in place of rivets.

The total cost of the floating structure was 19,000 Kronen.

The time occupied in erecting the temporary bridges in place was from May 20 to June 30, equal in average to 10 days for each pair of bridges in one opening. A few days later (July 6) the whole of the falseworks supported by the bridges were terminated. The chain plates were transported to the bridge as far as chain joints 14 and 15, on either side of the river, by means of small trucks running on stagings standing at a height of 9 m. above water level and passing by both sides of the towers. At each of these four points indicated an electric hoist was installed—each one of 5.2 HP., running at 600 revolutions with a tension of 400 volts and having a lifting capacity of 2,000 kgs. at a speed of 6 meters per minute. The cost of this installation was 17,800 Kronen.

The plates, duly stiffened with timbers to prevent buckling, were run up to the height of 36 m. above water level, where, by means of a traveling crane on an upper staging, the plates were distributed to the fitters below, according to requirements, the plates being lowered down a chute or slide formed of timber balks bolted to the posts of the falseworks.

At the eye-bar joints actually being packed—this work proceeding simultaneously at four points—the final adjustments were made by means of small hand-cranes.

The sequence of operations followed in the chains' erection may be summarized as follows:

The upper and lower suspension arms in all four towers were erected in three weeks (April 17 to May 17) and connection with the anchor chains (by the rolling-bolts) was first effected at joint No. 10 of the upper chain and subsequently at joint No. 9 in the lower line of eye-bars—this, therefore, completing all work on the anchorage chains.

The erection of the lower main-chain was commenced May 23 and by July 26 it was complete and its timber stoolings and wedges removed. The upper chain was, in its turn, completed by August 13—the two main-chains occupying barely 12 weeks for their entire erection. The relative stages of simultaneous advance upon the chains and upon the work of erecting the temporary bridges may be traced by the reader from the dates which are given. By Sept. 14 all temporary bridges had been removed and the trestle piers were next pulled up. The whole of the falseworks in the channel opening were struck by Nov. 19 following.

The stiffening trusses were next advanced (during July and August) between panel points 13 and 18 and connected up to the suspenders with the aid of falseworks which were still standing between those points.

The free erection of the bridge commenced Sept. 19, with the aid of the same floating stagings before described but now divided into two parts, each supported by two pontoons, and by means of which the total of 40 panels from panel points 18 to 38 (on either side of the bridge) were erected including the cross-girders, the verticals of the stiffening trusses, the lower chords of the stiffening trusses, the wind bracing and the three middle rows of stringers. The members of the cross-girders were erected and the verticals of the stiffening trusses were erected and riveted up upon the quay erection floor and then floated out and at once hung to the suspenders, the whole of the cross-girders being so completed (save No. 38) by Nov. 16.

The erection of the upper chords and of the diagonals of the stiffening trusses was carried out by means of an erecting floor laid over the cross girders. In the side openings a decking 6 m. wide was laid across the three middle stringers, on which was fixed the service tracks for the transport of various members.

For the riveting up of the lower chords of the stiffening trusses a 3½ m. wide scaffolding was suspended beneath the same members. The work of reinforcing the anchorages was, as previously mentioned, then commenced, and between September and October of the same year the anchor-chain falseworks were struck to make place for the new masonry work above the anchorages. Later on (April 25, 1903,) the completion of the work in the middle panels of the bridge was recommended, from the point of operations visible in Fig. 14A. This comprised the floor bearers, the street railway electric conduits and the secondary cross-girders; the gas mains and telephone conduits beneath the promenades, Zore's trough decking, buckled-plate flooring; and finally the rails for street-railway and the asphalt and beton laying were completed by July 1, ready for the wood pavers. In the month of August the

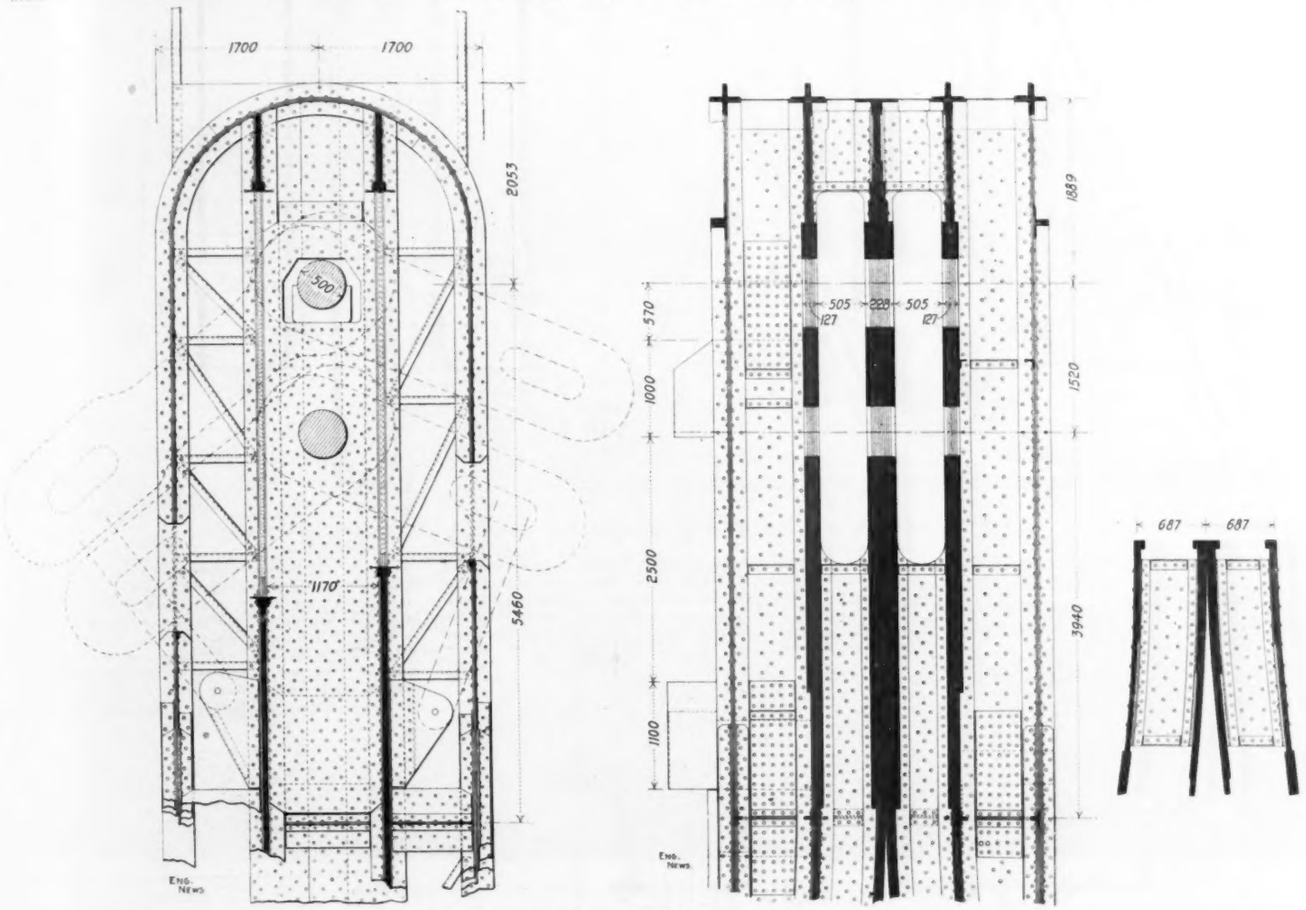


FIG. 11. DETAILS OF TOP SECTION OF TOWER LEGS.

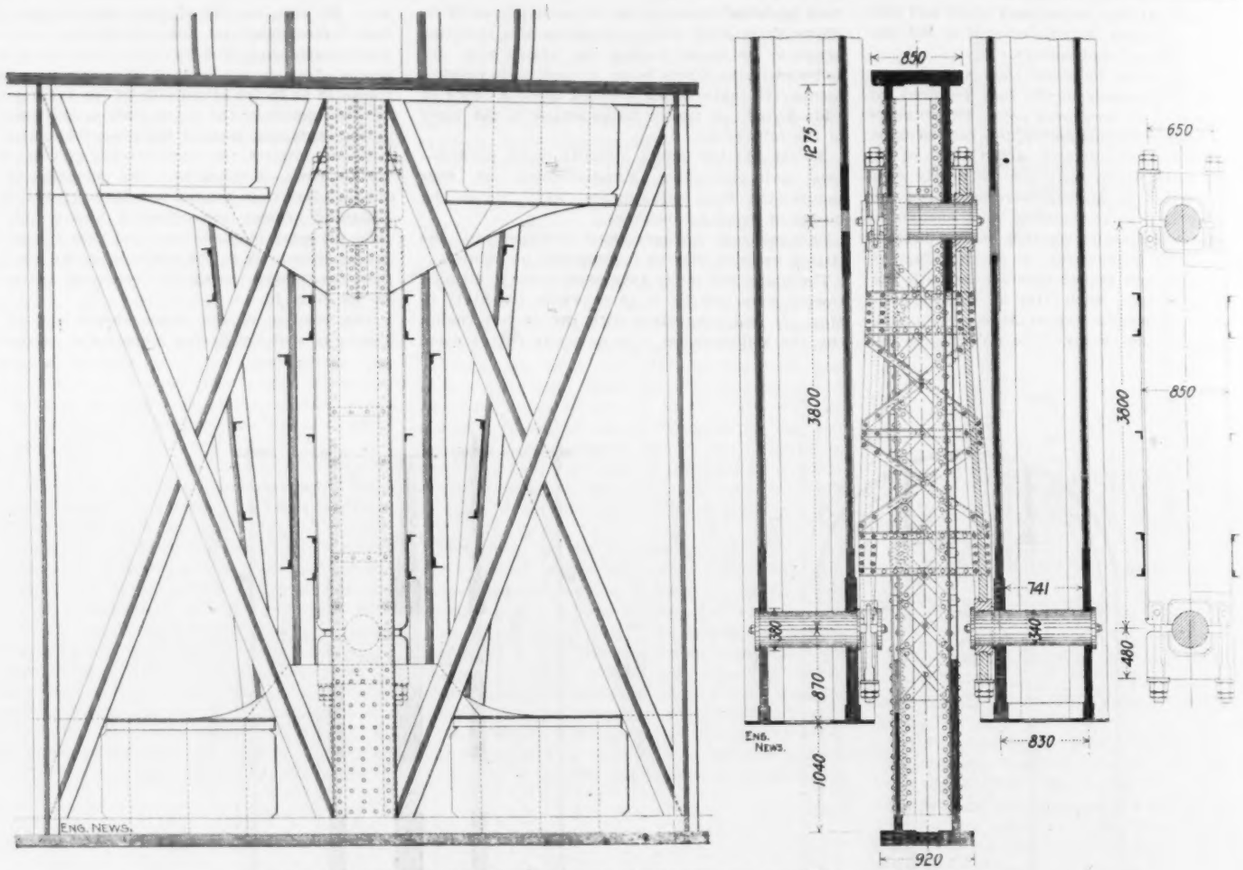


FIG. 12. DETAILS OF ROCKER POST SUPPORT FOR TRUSSES AT TOWERS.

tower falseworks were struck. These had served for the final painting—which work had been in general carried on contemporaneously with the structural work. In the shops and in the field a total of 94,000 kgs. of paint materials were used, costing 59,000 Kronen.

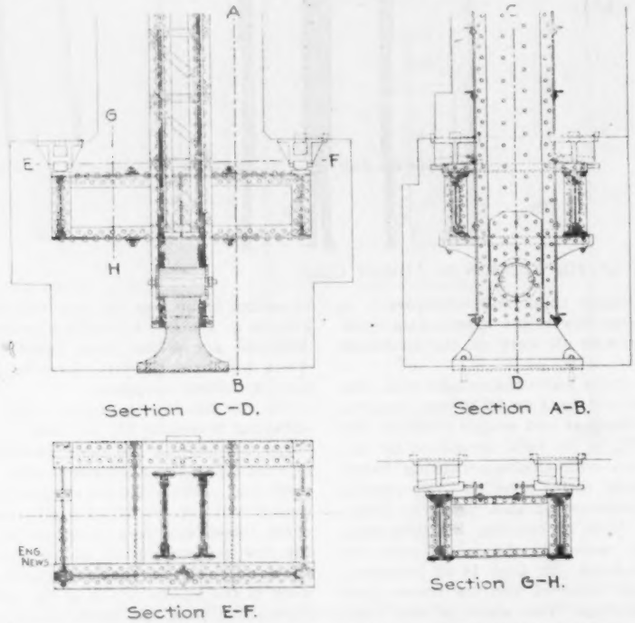


FIG. 13. DETAILS OF END ANCHORS OF STIFFENING TRUSSES.

THE RAILWAYS OF WESTERN AUSTRALIA, which are owned and operated by the government of that colony, had a total length of 1,541 miles on June 30, 1904, according to the annual report recently issued. Only 62 miles are double track. New lines, aggregating 23¼ miles, had been opened during the year, while an extension of 64 miles was under construction. The cost of the railways has averaged $29,170 per mile, and the operating expenses represented 74.28% of the earnings for the year covered by the report. The railways are of 3 ft. 6 ins. gage, laid with tee rails of 35 to 60 lbs. per yd., spiked to jarrah wood ties; they have grades as steep as 2%, 3% and 4%, and curves as sharp as 600 to 900 ft. radius. The work in progress includes double-tracking, reducing grades and curvature, stone ballasting, etc. The water supply is a serious matter in this dry country, and a number of dams have been built to form reservoirs, while at one point a distilling plant has been put in to treat bad water. The equipment includes 329 locomotives, 269 passenger cars, 127 brake cars or cabooses, and 5,632 freight cars; all these are gradually being equipped with the vacuum automatic brake. The employees number about 5,600. The lines are worked on the block system, as follows: Sykes system, 2 miles; other electric block systems, 60 miles; electric staff, [illegible] miles; staff and ticket with telephones, 925 miles. There are 132 junction points equipped with interlocking plants, being 38.48% of the total number. Mr. W. W. Dartnell is Chief Engineer of Existing Lines, and Mr. E. S. Hall is Chief Mechanical Engineer. Mr. W. J. George is Commissioner of Railways.

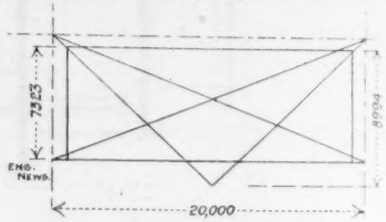


Fig. 14. Diagram of Wind Bracing at Ends of Shore Spans.

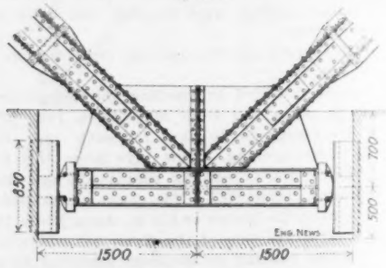


Fig. 15. Detail of Sliding Bearing of Wind Bracing on Anchorage.

STANDARD DESIGNS OF LOCOMOTIVES FOR INDIA.

For some years past there has been considerable trouble between the Indian railways and the European builders of locomotives, owing to the constant multiplication of designs by the motive power departments of the various lines, so that every order called for new designs and details, causing heavy expense in manufacture and consequent high prices, to which the railways objected. In addition to this, the variety of designs and the utter lack of uniformity has entailed much trouble and expense in the repair work. As a result, a committee to consider the adoption of standard designs was appointed by the British Engineering Standards Committee, at the request of the government of India. This committee has now made its report and presented standard designs, which have been adopted by the government.

These designs comprise complete plans for five types of locomotives as follows: For lines of the standard Indian gage of 5 ft. 6 ins.; (A) an eight-wheel passenger engine (4-4-0), and (B) a six-coupled freight engine (0-6-0); for the meter gage lines: (C) a ten-wheel (4-6-0) passenger engine, (D) a ten-wheel (4-6-0) mixed passenger and freight engine, (E) a heavy freight engine of the mastodon type (4-8-0). The designs were made with a view to embodying the best features of existing practice rather than to the preparation of entirely new designs. The principal dimensions of the five types of engines are given in the accompanying table:

LOCOMOTIVES FOR STANDARD GAGE (5 ft. 6 ins.)—The Belpaire firebox (with copper plates) has been adopted, as giving more steam and water capacity than the usual arrangement with semi-circular outside shell and girder stays for the fire-box crown sheet. The pressure is 180 lbs. The cylinders are inside, preferably cast in one piece, and have balanced slide valves driven by the Stephenson link motion through rocking shafts. The plate frames are kept straight throughout, and not set or spliced at the front end to give clearance for the play of the rear truck wheels, although this necessitates a somewhat narrower firebox than would otherwise have been obtainable. In the freight engine, the boiler, cylinders, valves and valve gear, journal boxes, etc., are as far as possible identical with those of the passenger engines. In both cases, the wheel diameters were adopted to allow of using tires identical with those of the largest number of engines of these types now existing in India.

The boiler is 4 ft. 8¼ ins. diameter, with a length of 11 ft. 4½ ins. between tube plates, and having 9-16-in. shell plates; the firebox is 7 ft. long. The tubes are 1¾ ins. outside diameter, reduced to 1⅝-ins. in the firebox tube plate and enlarged at the front tube plate as necessary. It is recommended that for a length of 12 ins. next the firebox they should be No. 11 S. W. G. in thickness, then tapering to No. 13 in a length of 12 ins.; the space between tubes should not be less than ¾-in. A screw reversing gear is recommended, with provision for a steam reversing gear later. There are to be four guide bars to each cylinder. Cast-steel wheel centers (with balance weights cast solid) are recommended, with 3-in. tires secured to the centers by a stud and lip fastening. The passenger engine truck is to be either of the sliding type or the double swing-link type. The tenders are to combine the steel frame of one road and the tank of another, and to be mounted on six 43-in. wheels with 3-in. tires. The engine and tender must be fitted with either the steam or vacuum brake, operated in conjunction with the vaccum train brake.

LOCOMOTIVES FOR METER GAGE (3 ft. 3⅜-ins.)—In these engines the Belpaire firebox (of copper), 180 lbs. pressure, and balanced slide valves are also used. The Walschaert valve gear, however, has been adopted, as being outside the frames and wheels, and easily examined and oiled. Some preference for outside frames on these narrow gage engines has been expressed, but this arrangement has not been adopted, as it is not much used and gives very little greater width of firebox. The boiler is 3 ft. 10½ ins. in diameter, 11 ft. 9 ins. long between the tube plates, and has ½-in. plates. The tubes are the same as in the other engines. There are to be two guide bars. The wheel centers are of cast steel, with 2½-in. tires. The tenders have 28½-in. wheels, and all engines and tenders are to be fitted with the continuous brake. The ordinary six-wheel tender, carrying 2,000 gallons of water and four tons of coal, is to be used with both the ten-wheel engines, but a special tender has been designed for the mastodon engine (4-8-0) in order to keep within the permissible stresses for bridges.

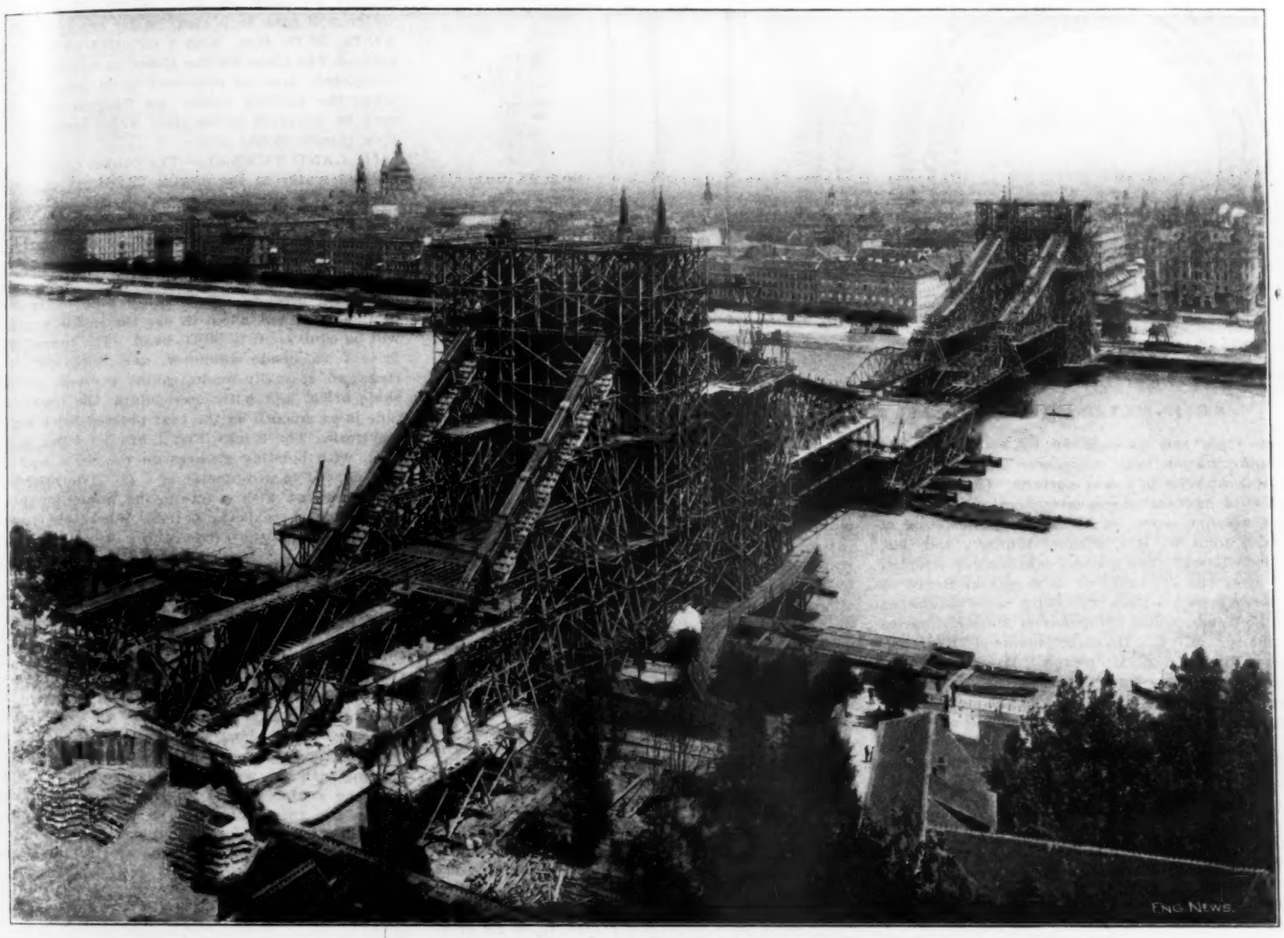


FIG. 16. GENERAL VIEW OF FALSEWORKS FOR ERECTING THE BUDAPEST SUSPENSION BRIDGE.

Standard Locomotives for Indian Railways.

	5 ft. 6 ins. gage.		3 ft. 3⅜ ins. gage.		
Class	Passenger	Freight	Passenger	Mixed	Heavy freight
Type	4—4—0	0—6—0	4—6—0	4—6—0	4—8—0
Driving wheels	6 ft. 2 ins.	5 ft. 1½ ins.	4 ft. 9 ins.	4 ft.	3 ft. 6½ ins.
Weight on drivers, gross tons	31.50	46.80	25.50	25.20	31.00
Weight of engine	50.00	46.80	33.00	32.50	39.00
Weight of engine and tender	89.35	86.15	56.00	55.50	63.00
Cylinders, ins	18¼ x 26	18½ x 26	15½ x 22	15 x 22	16 x 22
Cylinder volume, cu. ft.	8.09	8.09	4.80	4.50	5.12
Heat surface, tubes, sq. ft.	1255.80	1255.80	954.00	954.00	1161.00
Heat surface, total, sq. ft.	1385.80	1385.80	1062.00	1062.00	1287.70
Grate area, sq. ft.	26.00	26.00	16.00	16.00	17.00

PROGRESS OF WORK ON THE NEW WATER SUPPLY SYSTEM OF CINCINNATI, O.

The new water supply system of the city of Cincinnati, O., is now well advanced, although litigation and other troubles have delayed the completion beyond the date originally expected. It will be of interest at this time to review the present conditions of the several parts of the system. This review is based upon information obtained by a member of our editorial staff during a recent visit to Cincinnati.* The supply is now taken from the Ohio River by an intake and pumping station near the center of the city and below a number of sewer outfalls. In 1896 a report on a new water supply system was made by a commission appointed by the city, consisting of Messrs. John W. Hill, Samuel Whinery and Geo. H. Benzenberg. The general scheme was adopted and after the appointment of a special Board of Water-Works Trustees the plans were submitted to a new commission composed of Messrs. Charles Hermany, M. L. Holman, Clemens Herschel, Henry Flad and S. M. Felton. The report submitted in 1897 recommended further investigations as to means of improving the appearance and quality of the water, and suggested mechanical filtration as being worth consideration. In 1897 the Board of Trustees appointed Mr. Gustave Bouscaren as Chief Engineer, and Mr. Geo. H. Benzenberg and Mr. Charles Hermany as Consulting Engineers. Since Mr. Bouscaren's death in November, 1904, Mr. Benzenberg has been in actual and resident charge of the work, although he has declined the position of Chief Engineer, owing to his other engagements in consulting practice.

The new water supply system is designed to supply 60,000,000 gallons per day (for a present population of about 350,000), with provision for an increase to 90,000,000 gallons daily capacity. It comprises the following main features: (1) an intake tunnel with shaft and crib in the Ohio River and a shaft opening into a pump pit on shore; this intake is at California, about 6½ miles above the old intake; (2) an intake pumping station; (3) a purification plant comprising settling basins and mechanical filters; (4) a tunnel 4¼ miles long to the city; (5) a city pumping plant taking water from the tunnel and delivering it into the high service mains or to the Eden Park distributing reservoir (100,000,000 gallons capacity). The settling basins have an elevation of 140 ft. above low water, and the clear water basin, 96 to 76 ft. range; the center of the suction conduit at the city pumping station has an elevation of 47 ft.; while the elevation of high water level in Eden Park reservoir is 240.75 ft.

*Articles on the Cincinnati water supply system have been published in Engineering News as follows:
Reports on new works, April 2, 1896; May 6, 1897.
Descriptions of new works, Dec. 8, 1898; April 26, 1900; May 23 and Oct. 17, 1901; June 12, 1902.
Break in caisson at intake pumping station, May 30, 1901.
Filtration system, Feb. 23, March 9 and May 25, 1899; Sept. 24, 1903.
Land tunnel, Dec. 31, 1903.

(1) INTAKE TUNNEL AND SHAFTS.—The intake shaft is close to the Kentucky side of the river and is 7 ft. in diameter, with a tunnel 7 ft. in diameter and 1,426 ft. long leading to the Ohio side. The tunnel is lined with brick and has a grade of 3 ins. in 100 ft. from the river shaft down to the shore shaft. This latter shaft is 8 ft. in diameter. This work is all completed.

(2) INTAKE PUMPING STATION.—The shore shaft from the intake tunnel opens with a pump pit 98 ft. inside diameter and 85 ft. deep. The bottom of the pit is formed by a great timber caisson which was sunk into a firm bed of sand to within about 17 ft. of bed rock, and in view of the subsequent troubles it seems strange that it was not carried down to the rock. Early in 1901, two cracks appeared in the shaft masonry, below the caisson, showing that under the head due to high water in the river the water in the sand had forced the floor upwards, the maximum movement being about 5 ins. Investigations showed that the deck bulged up in the middle, there being no movement at the sides; they further showed that the movements were repeated with other stages of high water. A counterbalance weight was built on the center of the deck and this settled the floor back 2½ ins., but did not stop the movements. The driving of tunnels under the caisson and building a concrete foundation so as to form a solid connection between the caisson and bed rock has been proposed, but is not now considered necessary. The cracks were at first filled up, but afterwards this filling was cut out, all the pumping engine castings available were placed on the floor, and the pump pit was filled with water. At the present time the caisson has been forced back to within 1-1,000-ft. of its original level, and it is not anticipated that any further trouble will be caused, especially in view of the great weight of the pumping engines when completed. At this station there will be installed four vertical triple-expansion engines, each of 30,000,000 gallons daily capacity. The four engines have been built by the Camden Iron Works, of Camden, N. J., and are now being erected. Their three cylinders are 29, 54 and 82 ins. diameter and 96 ins. stroke, and the three pump plungers 37½ ins. diameter. The four 48-in. discharge pipes will be connected to two lines of 60-in. cast-iron pipe carrying the water to the settling reservoirs. There will be eight boilers of the Stirling water-tube type, 250 HP. each, with mechanical stokers. The coal bunker has a capacity of about 7,300 tons, and there is to be a complete coal and ash handling plant.

(3) PURIFICATION PLANT.—The treatment of the water will include sedimentation and filtration. There will be two settling basins, formed by damming and grading natural ravines, and these will have an available capacity of 345,000,000 gallons. The basins will be used alternately, to allow of cleaning, and the capacity is sufficient to allow the water to stand for two or three days for settlement. There has been great delay in this part of the work, owing to troubles with contractors, and it is now in the hands of the contractor, the Kieling & Ridge Co., of Pi... It is now hoped that the plant can be completed by October, 1906. The mud will be removed from the settling basins by flushing.

For the filtration of the water, careful ... were made by Mr. Geo. W. Fuller, and an ... mental plant was installed. His report, ... 1899, recommended mechanical filtration, ... was endorsed by a report submitted to the ... of Trustees in 1900 by Messrs. Bouscaren, ... berg and Hermany, the chief and consulting engineers. There will be 28 filter beds about ... × 28 ft. × 9 ft. deep, working at a rate of 125,... gallons per acre per day. From the filters the water will pass to a clear water reservoir ... × 400 ft., 20 ft. deep, with a capacity of 20,... gallons. The plans for the filters have not yet been completed, and no contracts have been let, but when the settling basins are finished the water may be delivered to the clear water reservoir and flow thence to the city.

(4) LAND TUNNEL.—The tunnel carrying the treated water to the city is 22,264 ft. long from the shaft at the clear water reservoir to that at the city pumping station. It is approximately parallel with the Ohio River shore line (but from 300 to 900 ft. distant) and has a down grade of 1 in 2,000 towards the city. Its top is 60 ft. below low water level or 130 ft. below high water level in the river, but when in use the inside pressure will be equivalent to 90 ft. head. The tunnel, Fig. 1, is 7 ft. inside diameter, and lined with two rings of specially-made radial pressed vitrified shale brick, laid with close joints; the inner surface is as smooth as the best pressed-brick building work. The bricks, Fig. 2, are 3 × 4 ins., 9 ins. long, with bonding grooves on the sides, and the face curved to a diameter of 7 ft. The brick lining is backed with concrete, the minimum thickness of concrete being 6 ins. Where the tunnel crosses beneath the Little Miami River, the lining is reinforced by rings of ¾-in. round steel bars, 2 ft. c. to c., as also shown in Fig. 1. The tunnel is completed, and in order to determine the amount of leakage, if any, it has been filled with water from the city mains. The tunnel was driven through limestone and shale rock, with about 25 ft. of rock above the crown. This rock was in some places badly shattered and much water was encountered. The pneumatic or air-lock system was tried for a short distance (350 ft.), but did not prove satisfactory. The successful method of dealing with the water consisted in driving pipes into the seams, so as to discharge the water within the tunnel; where the streams were too small and too numerous for this, aprons were put in to collect the water outside of the lining, the apron leading to a single pipe passing through the lining. In this way the brick lining and concrete backing were put in without trouble from washing, and the pipes were left projecting into the tunnel. After the work had set, the pipes were fitted with valves, and then cement grout was forced into them under 80 lbs. pressure; when no more grouting could be pumped in, the valve was closed and the grouting machine transferred to another pipe. The grouting was found to travel considerable distances, sometimes appearing at exposed pipes beyond where the grout was being forced in. The sealed pipes were left for 10 or 20 days.

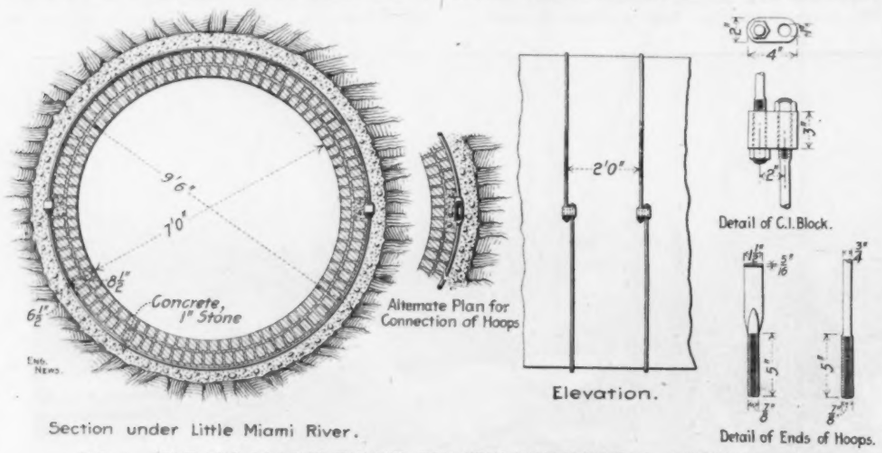


FIG. 1. SECTIONS OF LAND TUNNEL FOR NEW WATER-WORKS; CINCINNATI, O.

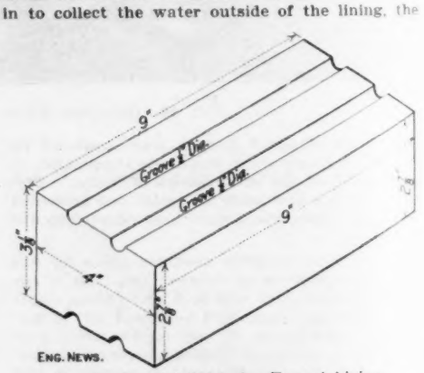
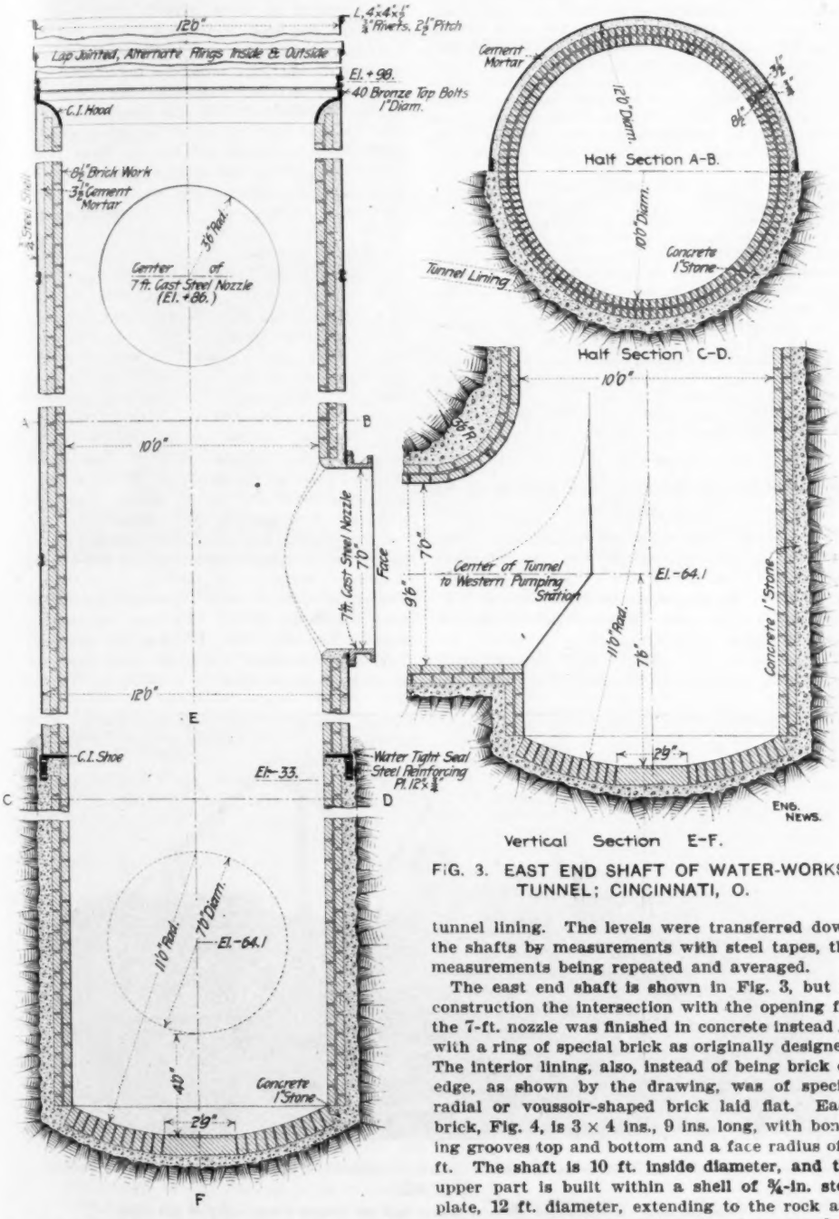


Fig. 2. Special Brick for Tunnel Lining.

...e thorough setting of the grout and they ... cut off a little back of the tunnel face, ... recess pointed up. In one place there ... pipes 1 to 2 ins. diameter in 1,000 ft. of ...

In spite of the seamy rock, with direct ...ion to the river, and in spite of the amount ...r encountered, the finished tunnel is very ... measured infiltration being only 10 gal... minute for the entire length.

...ets of gas were encountered at several ... and several small explosions occurred; six



Vertical Section E-F.

FIG. 3. EAST END SHAFT OF WATER-WORKS TUNNEL; CINCINNATI, O.

men were killed by gas explosions. Further trouble was prevented by providing an increase of ventilation from the compressed air mains which were supplying power for the rock drills. The gas was natural gas, and this with a little dilution with air is less explosive than marsh gas with much dilution.

The work was prosecuted by ten headings from the two permanent shafts and four intermediate shafts, the latter being afterwards sealed and filled and the tunnel lining carried past them. As the center line of the tunnel makes one or more angles between each pair of shafts, the survey work was somewhat complicated, more especially as buildings and other obstacles prevented direct sights on some of the tangents. The tangents were measured several times at different temperatures and the average distances taken. The angles were also repeated and averaged, each angle being measured no less than ten times and by at least three observers. For the levels, bench marks were established at ½-mile intervals. The line was transferred down the shafts by two wires, kept taut by 20-lb. weights in glass jars filled with glycerine. The wires being adjusted to line by the transit over the shaft, were then used by the tunnel transit to project the line upon scales set 300 ft. apart and attached to anchors in the tunnel lining. The levels were transferred down the shafts by measurements with steel tapes, the measurements being repeated and averaged.

The east end shaft is shown in Fig. 3, but in construction the intersection with the opening for the 7-ft. nozzle was finished in concrete instead of with a ring of special brick as originally designed. The interior lining, also, instead of being brick on edge, as shown by the drawing, was of special radial or voussoir-shaped brick laid flat. Each brick, Fig. 4, is 3 × 4 ins., 9 ins. long, with bonding grooves top and bottom and a face radius of 5 ft. The shaft is 10 ft. inside diameter, and the upper part is built within a shell of ¾-in. steel plate, 12 ft. diameter, extending to the rock and having a water-tight seal. The rings are 6 ft. high, with three plates to a ring and 16-in. triple-riveted vertical cover plates. In the lower part the rings are butt-jointed, with inside 6-in. single-riveted cover plates; but at the top the rings are lap jointed and set alternately inside and outside. The contractors for the tunnel were W. J. Gawne & Co.

(4) CITY PUMPING STATION.—The new city pumping station is located on Eastern Ave., near Lumber St., and consists of a stone engine house 350 × 65 ft., a brick boiler house 270 × 60 ft., and two brick buildings each 117 × 69 ft. There will be six vertical triple-expansion engines, three of 25,000,000 gallons capacity and three of 12,000,000 gallons capacity, to be built by the Holly Mfg. Co. These have not yet been installed. There will be 12 boilers of the Geary water tube type of about 200 HP. each, carrying 160 lbs. pressure and fitted with mechanical stokers. The coal bunkers have a capacity of about 7,600 tons, and there will be a complete coal and ash handling conveyor system. Coal can be delivered here by barges or cars. From this station the main supply will be pumped to the Eden Park reservoir, as already noted, whence it will flow by gravity to the mains. For the high-service districts, however, a special line of mains will be laid into which the water will be pumped directly at the pumping station.

ENGINEERS.—The work is now under the direction of Mr. Benzenberg as Acting Chief Engineer, with Mr. Hermany as Consulting Engineer, the former being now practically resident at Cincinnati. Mr. C. N. Miller is Assistant Engineer in charge of the office, and Mr. E. G. Manahan is Engineer in charge of the filtration works. Mr. Wm. C. Jewett is Resident Engineer on the construction of the settling reservoirs. Mr. John A. Hiller was Resident Engineer on the construction of the land tunnel (completed), and is now in charge of the laying of water mains, and also the grading, foundations and buildings at the western (city) pumping station.

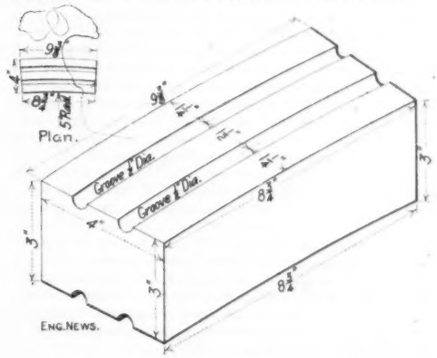


Fig. 4. Special Brick for Shaft Lining.

It is expected that the plant will be completed in about two years. The estimated cost of the completed system is $10,000,000.

STATISTICS OF RAILWAYS IN THE UNITED STATES FOR THE YEAR ENDING JUNE 30, 1904.

The statistician of the Interstate Commerce Commission has issued advance summaries of the statistics of railway operation that have been collected and compiled for the seventeenth annual statistical report of the Commission, which will appear this fall. The following abstract gives the essential parts of these summaries:

MILEAGE.—The total single track railway mileage in the United States on June 30, 1904, was 213,904.34 miles, having increased 5,927.12 miles in the year ending on that date. This increase exceeds that of any previous year since 1890. An increase in mileage exceeding 100 miles is shown in 19 States and Territories. The operated mileage, concerning which substantially complete returns were made, was 212,243.20 miles. The aggregate length of railway mileage, including tracks of all kinds, was 297,073 miles, classified as follows: Single track, 212,243 miles; second track, 15,824 miles; third track, 1,467 miles; fourth track, 1,046 miles, and yard track and sidings, 66,492 miles. There was an increase of 13,251 miles in the aggregate length of all tracks, of which 4,932 miles, or 37.22% were due to the extension of yard track and sidings.

The number of railway corporations included in the report was 2,104. Of this number 1,086 maintained operating accounts, 848 being classed as independent operating roads and 238 as subsidiary roads. In the course of the year railway companies owning 5,600.18 miles of line were reorganized, merged, consolidated, etc. The length of mileage operated by receivers on June 30, 1904, was 1,323 miles, an increase of 137.83 miles as compared with the previous year. The number of roads in the hands of receivers was 28, and at the close of the previous year 27, 6 roads having been taken from the hands of receivers and 7 having been placed in charge of the courts.

EQUIPMENT.—On June 30, 1904, there were in the service of the railways 46,743 locomotives; as classified, these locomotives were: Passenger, 11,252; freight, 27,029; switching, 7,610, and 852 not assigned to any class. The total number of cars of all classes was 1,798,561; the assignment of this rolling stock was, to the passenger serv-

ice, 39,752 cars; to the freight service, 1,692,194 cars; the remaining 66,615 cars being those employed directly by the railways in their own service. Cars used by the railways that were owned by private companies and firms are not included in this statement. The average number of locomotives per 1,000 miles of line was 220. The average number of cars per 1,000 miles of line was 8,474. The number of passenger-miles per passenger locomotive was 1,948,384. The number of ton-miles per freight locomotive was 6,456,846.

The aggregate number of locomotives and cars in the service of the railways was 1,845,304. Of this number 1,554,772 were fitted with train brakes, indicating an increase during the year of 92,513 and 1,823,030 were fitted with automatic couplers, indicating an increase of 52,472. Practically all locomotives and cars in passenger service had train brakes, and of the 11,252 locomotives in that service 11,113 were fitted with automatic couplers. Only 922 cars in passenger service were without automatic couplers. With respect to freight equipment it appears that most of the freight locomotives had train brakes and automatic couplers. Of 1,692,194 cars in freight service on June 30, 1904, 1,434,386 had train brakes, and 1,674,427 automatic couplers.

EMPLOYEES.—The number of persons on the pay rolls of the railways in the United States, as returned for June 30, 1904, was 1,286,121, or 611 per 100 miles of line. With regard to the four general divisions of railway employment, it appears that general administration required the services of 48,746 employees; maintenance of way and structures, 415,721 employees; maintenance of equipment, 261,819 employees, and conducting transportation, 566,708 employees. The amount of wages and salaries paid to employees during the year was $817,598,810.

CAPITALIZATION.—The par value of the amount of railway capital outstanding on June 30, 1904, was $13,213,124,679, which represents a capitalization of $64,265 per mile. Of this capital $6,339,899,329 existed as stock, of which $5,050,529,469 was common and $1,289,369,860 preferred, and the remaining part, $6,873,225,350 as funded debt which consisted of mortgage bonds, $5,746,898,983; miscellaneous obligations, $723,114,986; income bonds, $229,876,687, and equipment trust obligations, $173,334,694. Of the total capital stock outstanding $2,696,472,010, or 42.53%, paid no dividends.

PUBLIC SERVICE.—The number of passengers carried by railways in the year ending June 30, 1904, was 715,419,682, indicating an increase of 20,528,147 as compared with the year ending June 30, 1903. The passenger-mileage, or the number of passengers carried 1 mile, was 21,923,213,536, having increased 1,007,449,655.

The number of tons of freight reported as carried (including freight received from connecting roads and other carriers) was 1,300,899,105, which exceeds the tonnage of the previous year by 5,504,842 tons. The ton-mileage, or the number of tons carried 1 mile, was 174,522,089,577, the increase being 1,300,810,584. The number of tons carried 1 mile per mile of line was 829,476, which figures indicate a decrease in the density of freight traffic of 25,966 ton-miles per mile of line.

The average revenue per passenger per mile for the year mentioned was 2.006 cts., the average for the preceding year being the same. The average revenue per ton mile was 0.780 ct. This average for the preceding year was 0.763 ct. Earnings per train mile show an increase for passenger but a decrease for freight trains. The average cost of running a train 1 mile appears to have increased between 4 and 5 cts. The ratio of operating expenses to earnings, 67.79%, also increased in comparison with the preceding year, when it was 66.16%.

EARNINGS AND EXPENSES.—The gross earnings from operation were $1,975,174,091. Their operating expenses were $1,338,896,253. The net earnings amounted to $636,277,838. The amount of income obtained from other sources than operation was $212,933,999.

ACCIDENTS.—The total number of casualties to persons was 94,201, of which 10,046 represented the number of persons killed and 84,155 the number injured. Casualties occurred among three general classes of railway employees, as follows: Trainmen, 2,114 killed and 29,275 injured; switch tenders, crossing tenders, and watchmen, 229 killed, 2,070 injured; other employees, 1,289 killed, 45,722 injured. The casualties to employees coupling or uncoupling cars were: Employees killed, 307; injured, 1,019. The casualties connected with coupling and uncoupling cars are assigned as follows: Trainmen killed, 269; injured, 3,506; switch tenders, crossing tenders, and watchmen killed, 23; injured, 420; other employees killed, 15; injured, 93. The casualties due to falling from trains, locomotives or cars in motion were: Trainmen killed, 457; injured, 4,757; switch tenders, crossing tenders and watchmen killed, 25; injured, 301; other employees killed, 75; injured, 570. The casualties due to jumping on or off trains, locomotives, or cars in motion were: Trainmen killed, 116; injured, 3,926; switch tenders, crossing tenders and watchmen killed, 14; injured, 278; other employees killed, 61; injured, 506. The casualties to the same three classes of employees in consequence of collisions and derailments were: Trainmen killed, 613; injured, 4,337; switch tenders, crossing tenders and watchmen killed, 20; injured, 138; other employees killed, 90; injured, 854.

The number of passengers killed in the course of the year 1904 was 441 and the number injured 9,111. In the previous year 355 passengers were killed and 8,231 injured. There were 262 passengers killed and 4,978 injured because of collisions and derailments. The total number of persons, other than employees and passengers, killed was 5,973; injured, 7,977. These figures include the casualties to persons classed as trespassing, of whom 5,105 were killed and 5,194 were injured. The total number of casualties to persons other than employees from being struck by trains, locomotives, or cars was 4,749 killed and 4,179 injured. The casualties of this class were as follows: At highway crossings, passengers killed, 4; injured 10; other persons killed, 804; injured, 1,453; at stations, passengers killed, 28; injured, 108; other persons killed, 458; injured, 525; at other points along track, passengers killed, 9; injured, 38; other persons killed, 3,446; injured, 2,045. The ratios of casualties indicate that 1 employee in every 357 was killed and 1 employee in every 19 was injured. With regard to trainmen—that is, enginemen, firemen, conductors, and other trainmen—it appears that 1 trainman was killed for every 120 employed and 1 was injured for every 9 employed.

In 1904, 1 passenger was killed for every 1,622,267 carried, and 1 injured for every 78,523 carried. For 1903 the figures show that 1,957,411 passengers were carried for 1 killed, and 84,424 passengers were carried for 1 injured. For 1895, 1 passenger was killed for every 2,984,832 carried and 1 injured for every 213,651 carried. With respect to the number of miles traveled the figures for 1904 show that 49,712,502 passenger-miles were accomplished for each passenger killed, and 2,406,236 passenger-miles for each passenger injured. For 1903 the figures were, 58,917,645 passenger-miles for each passenger killed, and 2,541,096 passenger-miles for each passenger injured. The figures for 1895 show that 71,696,743 passenger-miles were accomplished for each passenger killed and 5,131,977 passenger-miles for each passenger injured.

THE HANDLING OF MATERIAL FOR FILLING GRANT PARK, CHICAGO.

In the record of progress of the Chicago tunnel construction, in our issue of July 20, reference was made to the use of the excavated material for filling in the site of Grant Park, on the lake front, and we have since obtained information as to the dumping equipment used.

The tunnel cars have steel underframes mounted on trucks of 24 ins. gage, they carry removable wooden bodies of 4 cu. yds. capacity, the bottoms of which are attached by chains in such a way that when the chains are released the bottom falls away entirely clear of the sides, so there is no obstruction to the dropping of the sticky tough clay. The electric locomotives of the tunnel service deliver these cars on the bank at the park site, where they are taken in hand by the contractor for the filling. Small four-wheel locomotives take trains of these cars to a dumping derrick of 20 tons capacity, with a 65-ft. boom, and weighing 75 tons. This picks up a loaded car body, swings it into position, dumps the load, and puts the empty body back on the underframe. The lower block of the hoisting cable is attached to a horizontal rectangular steel frame, with chains at the corners, which are attached to [illegible] corners of the car body. Fig. 1 shows this [illegible] chine at work, with a car body suspended [illegible] the bottom, and the bottom of the car body sw[illegible] clear for dumping. The derrick is of special [illegible] sign, and is peculiar in being mounted on runn[illegible] In moving it ahead, pieces of old piles are [illegible] down, and the runners are greased so as to sl[illegible] easily as the machine hauls itself along by a [illegible] ble, the fill being much too soft for the use [illegible] rollers. The dumping of material goes on wh[illegible] the machine is being moved. The feet of [illegible] stiff-legs are held in heavy castings but are n[illegible] bored for any bolts, one heavy bolt through [illegible] jaws of the castings being the only fastenings. [illegible] transverse A-frame transmits the weight of t[illegible] engine, boilers, etc., to the frame carrying [illegible] stiff-legs, so that no stones or other weights r[illegible] quire to be piled at the feet of these stiff-le[illegible] One man operates the derrick; he fires the boil[illegible] handles the engine drums for hoisting the loa[illegible] and swinging the boom, and also releases the bo[illegible] tom of the car to dump the load.

A similar derrick is in use at the north end o[illegible] the park for unloading material brought in wag[illegible] ons. This machine, shown in Fig. 2, is of 1[illegible] tons capacity and has a 50-ft. boom. The wagons have removable bodies similar to those of the tunnel cars, above described, but of 3 cu. yds. capacity, and in Fig. 2 the machine has a wagon body suspended ready to dump. On the roadway stands the wagon bed and team. The machine can remove, dump, and replace a wagon body in one minute, and it has a record of 55 wagons handled in 60 minutes. Besides clay from the tunnel shafts, these wagons bring the wreckage of old buildings that are being torn down, and also the material excavated for the foundations, basements and sub-basements of new buildings on the same or other sites. The removal of material from these deep excavations is often a difficult matter, and was discussed in our issue of Dec. 22, 1904. Raising and lowering the wagons by derricks has been tried, and also the hauling of small cars by a cable up an incline,

FIG. 1. 20-TON DERRICK DUMPING TUNNEL CARS FOR FILLING IN AT GRANT PARK, CHICAGO.

(The car body is suspended from a frame and its bottom hangs clear of the sides.)

ending at a platform above the street, where the material is dumped into a hopper, and thence discharged into wagons standing below. At the new Heyworth Building a special inclined conveyor was used, having arms which engaged with the car axles. With the rapid extension of the tunnels, however, much of this hoisting of material and hauling it through the streets by wagons will be done away with. At several building sites the wreckage and excavated material have been handled by the tunnel cars and one new 18-story building has a sub-basement 40 ft. below the street level, reached by a branch tunnel which will later be used for handling freight, etc., for this building.

Returning to the derricks, it is to be noted that

work night and day, although most of the material is handled between 4 p. m. and in., as during the day the concrete lining is in for the tunnel excavated during the night. om 1,000 to 1,500 cu. yds. have been dumped ne day. With the 10-ton derrick only three are required; one at the derrick and two on ground. One of the latter is the teamster the other attends to the chains.

n interesting feature of the work is the pat- d roadway over which the wagons are hauled he derrick. The surface of the filled ground is

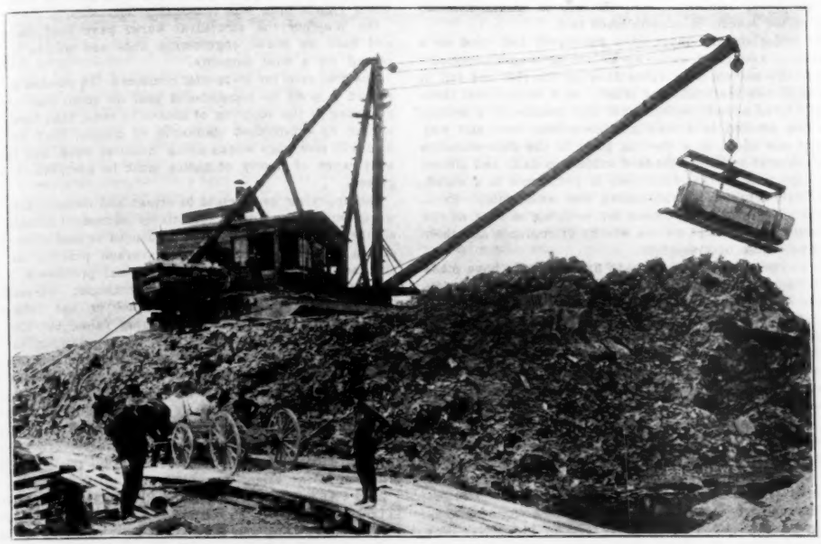


FIG. 2. 10-TON DERRICK DUMPING WAGONS FOR FILLING IN AT GRANT PARK, CHICAGO.
(The wagon body is suspended ready to be dumped by the derrick man.)

very rough and irregular, and quite soft, and in order to ensure a steady and continuous movement of the wagons a good roadway is required, but this must be very cheap as it is only temporary. The construction is shown in Fig. 3. Old railway ties, A, A, are laid down and on them are old 6-in. or 8-in. I-beams, B, laid flat, with fillers under the webs. These beams form the trackways, and on each side of them are spiked timbers C, C, which hold them in place. With two-horse wagons, the horses usually walk on these timbers, but planks can be laid in the middle space if desired, and this is done in the roadway shown in Fig. 2.

This work of handling and dumping material at the park site is in the hands of the W. J. Newman Co., 84 La Salle St., which has a contract with the Illinois Tunnel Construction Co. It has been at work for four years, and it is expected that two more years will be required to complete the work. The car and wagon bodies, many details of the derricks, the car conveyor, and the wagon roadway were designed and patented by Mr. W. J. Newman, to whom we are indebted for much of the information given. The derricks and the methods of handling material with them are claimed to be adaptable to the building of railway embankments or any kind of bank or fill. It may be noted that at Grant Park the work of filling is somewhat complicated by the requirements of the park authorities in regard to the surface. Instead of a flat, level surface there will be hills and valleys and slopes, and the contractor is required to put in the filling to correspond to the plans of the landscape engineers.

THE PRINCIPLES GOVERNING THE VALUATION FOR RATE-FIXING PURPOSES OF WATER-WORKS UNDER PRIVATE OWNERSHIP.*

By Arthur L. Adams,† M. Am. Soc. C. E.

The constantly increasing interest among the thinking people of this country in the evolution of some process by which so-called "public service corporations" may be brought under such government control of rates charged by them as will secure protection to the public against unfair discrimination, insure the making of no greater average charges for the service rendered than such service is reasonably worth, and at the same time will afford such properties immunity from spoliation under the guise of lawful regulation, is justification for the careful consideration of any important aspect of this very important subject.

That many of the problems involved are of a character calling for solution by those familiar with works construction and management, and that the aid of such men is frequently sought to assist the courts in reaching right conclusions in cases arising under existing laws, fully warrants in the opinion of the writer this presentation.

Legislation on the subject may as yet be regarded as in an experimental stage; and the resulting accumulation of experience has demonstrated the unwisdom of many of the methods employed in attempts to establish such control.

The whole subject needs most careful consideration by those whose training best fits them to devise methods with a clear vision as to their practical consequences.

The regulation of rates by governmental agency, whether such regulation takes the form of the fixing of rates outright or the revision of rates made by the corporation, presupposes the right of the corporation to receive a fair and just return upon the value of its property.

The ascertainment of what constitutes the fair and equitable value of such properties is always the important initial step. It gives rise to most interesting and complex questions involving the consideration of ways, means, and cost of construction; of the subsequent practical conduct of such works as to their operation, maintenance, growth, and financial management, and the value to the public of the service rendered. It also calls for the exercise of the judicial temper, a keen sense of justice and fair dealing, and often no small measure of imperviousness to public criticism.

The first before mentioned requirements are certainly such as must be possessed by any successful engineer of high professional standing; and impartiality, discriminating judgment, and equanimity under trying conditons should certainly characterize the members of a profession so often called upon to decide between contending interests.

It is, therefore, the writer's belief that our profession will fail of its privileges and its duty if it does not influence in a very large degree the final formulaton of wise legislation on this subject, and sound court interpretations.

The principles governing the determination of value of all such properties are quite similar; and, though this paper deals with but one class as its title indicates, the writer hopes it may prove of interest to specialists in other lines.

No effort will be made to treat the subject of appraisement even of water-works in all its aspects, but rather to assume conditions likely to prevail in bringing most public service corporations under governmental control or supervision as to rates.

By the adoption of certain premises it is intended that all exceptional cases arising from special contracts, special legislation, or otherwise, shall be turned aside and the question become a general one as to what under the more ordinary circumstances constitutes the just and reasonable value of water-works properties of private corporations devoted to and being used for the public convenience. And even when thus restricted the limitations of space will limit the writer to the discussion of the leading principles and factors only.

It is, therefore, presupposed: (1) That works are built under legal authority imposing no restraints affecting their value. (2) That the value of the property is sought as the basis for the fixing of such rates by governmental authority as shall return the owners a fair and just compensation for the service which is rendered.

FUNDAMENTAL FACTORS INFLUENCING VALUE.—The question of what constitutes reasonable and just value under the above conditions ordinarily necessitates the consideration of the following questions:

(1) Is the plant of such character as to enable it to properly fulfill the obligations which it has assumed of supplying the public with a suitable water service, both present and future?

(2) What has been the cost of the works?

(3) Has its acquisition been characterized by the exercise of a reasonable degree of prudence and engineering skill?

(4) Has the policy of the rate fixing authorities been such as to make necessary any special financial policy in the conduct or acquisition of the water-works properties, with special reference: (a) To the refunding of capital invested in structures of perishable character, or having a usefulness limited as to time? (b) To the allowing of interest returns upon the properties acquired for future use of an increasing population?

(5) Would a reduplication of the existing structural works cost less or more than the present structural works have cost?

(6) Would the construction of substitutional works cost less or more than the present works have cost?

(7) Have the real estate and water-producing properties of the company increased in value?

(8) Has the franchise any value?

(9) Does any special value attach to the fact that the company has an established business capable of producing an adequate revenue?

(10) Does the value of the service rendered to the consumers limit the value of the property?

No single formula can be made sufficient for the determination of value in all cases. Each of the above enumerated factors and possibly others may, under certain circumstances, properly exercise an influence in determining the final result. The degree of weight which attaches to each may vary greatly with circumstances. No final conclusion can be intelligently reached until all have been considered and their relative importance weighed, often one against the other.

Value is, therefore, not a quantity which can be determined with any mathematical accuracy. Its limitations as to maximum and minimum can usually be fairly well defined. When circumstances require the naming of a specific figure it can only be reached by the final, possibly arbitrary, exercise of personal discretion after reasoning processes have so far as possible narrowed the field of its final employment.

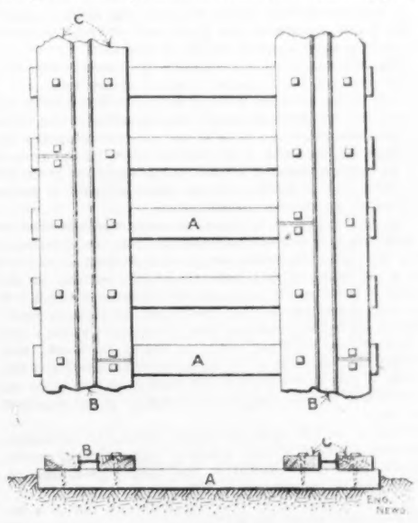


Fig. 3. Roadway for Contractors' Wagons.
W. J. Newman, Chicago, Inventor.

The application of the result, however, in determining rates is of itself subject to no absolutely defined rule and admits of a considerable range of use without doing violence to natural standards of fairness and equity.

That value, therefore, cannot be determined with mathematical nicety does not detract from the usefulness of a conclusion, though it be in a sense approximate only.

The before enumerated fundamental queries will now be taken up in their order for the purpose of showing their

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relation to reasonable value and to some extent the manner of their application. These factors are so closely inter-related that it requires careful analysis to make clear their bearings the one toward the other, and the limitations which each imposes upon the result sought.

THE FITNESS OF THE PLANT, BOTH PRESENT AND FUTURE.—The relations between the public and the water company are of a mutual character. If the public owe the company a sufficient revenue to operate and maintain its plant and pay to its owners a reasonable return upon its value, no less does the company owe to the public an abundant and uninterrupted supply of good potable water. It owes the exercise of such energy, prudence, skill, economy, and capital as will successfully anticipate contingencies of accident or increased demand, and such as will at all times enable it to supply water at the least cost to the consumer consistent with justice to its stockholders.

Fair treatment and a fair valuation on one side presupposes the maintenance of an efficient and economical service on the other, and the vice versa is equally true. It is, therefore, proper that inquiry be made into the character of the plant used and intended for supplying water. Such an inquiry, particularly in regions of lesser rainfall, naturally fall into the following order:

(1) The water supply as already developed as to quantity and quality. (2) The adequacy and suitability of the provision for future increase. (3) The present consumption and possible future demand. (4) The suitability of the works for conveyance and distribution.

The scope and character of the investigations necessary to develop the desired information embraced under these various heads will, of course, differ greatly in different cases. With but one exception they call for no comment here. The appropriateness of each subject in determining value would seem to be beyond question. The second has, however, been called in question and claims attention. It has been contended often, and even so held by certain courts, that in determining value only properties actually employed for the delivery of water or maintenance of the service at the time in question should be included. In view of this sentiment it is well, therefore, to remember that the duty of a water company to maintain an efficient service implies and imposes the responsibility for anticipating the future increase of consumption, that the available supply may never for one moment fall below the proper and legitimate demand.

This responsibility in the supplying of a city means the forecasting often for many years, of the probable population and per capita consumption.

It often means the necessity for the acquisition of necessary lands, water rights, and storage reservoirs years in advance of their actual use for the delivery of water, lest when imperatively needed they be impossible of acquirement or are purchasable only at a prohibitive price.

The building of structures of the magnitude often required is in itself not infrequently a work of several years.

It therefore follows that at all times the water company must know in advance just where and in what quantities its future water supplies are to be secured.

The relation of such acquisition to present value will more appropriately be taken up under a later head.

THE COST OF THE WORKS AND ITS RELATION TO VALUE.—Cost alone is seldom determinative of the value of any enterprise. Such value may be very materially influenced by the worth of the business—that is, the amount of its earning capacity, present and prospective; or by the probable cost of building a new plant of equal or better efficiency, or by other considerations.

But in the case of a system of water-works devoted to public use at a rate of compensation fixed, not by its owners, but by governmental agency and so fixed as to yield as a net return a moderate rate of interest only on the value of the property employed, the reasonable actual cost of such properties to their owners would seem to represent in almost all cases the lowest value upon which a rate schedule can with any claim to equity be based; and, though said cost may be by no means determinative of full value, it may be regarded as the most important factor involved and the one usually determinative of the minimum of value.

Reasons for this view are simple, direct, and conclusive, because founded on the practical necessities of water-works construction, operation, and financial management. They may be enumerated as follows:

(a) The purveying of water in a modern city is a necessity, upon which the welfare and very existence of the community depends. This service must, therefore, for the public good, be performed by either private or public initiative, regardless of how great may be the necessary cost.

(b) When rates are so fixed as to cover only the expense of maintaining the plant in a serviceable condition and pay a current rate of interest on the value of the property, such a policy precludes the company's making any financial provision for safeguarding its investments against depreciation by subsequent reductions in the market price of materials and labor, or otherwise.

(c) Water-works properties of magnitude are never created at one time. They are the product of years of growth, being increased and extended a little at a time from year to year in compliance with the demands of the community growth. In many western states water service must largely precede instead of follow population, while the supply must always be maintained in quantity well in advance of present demand.

(d) The imagining of a system created as of one time at current prices of lands, materials, and labor, is wholly fanciful and has never supplied a large city with water, though such an assumption, as we shall see, at times has its use.

(e) The final test of accuracy in every estimate is the actual cost of the completed works, built as such works are of necessity actually built. Actual cost of the completed works must, therefore, be entitled to far greater weight in determining their value than any mere estimate resulting from the unavoidable assumption of impossible or unnatural conditions, and the use of assumptions in lieu of the results of accomplished fact.

(f) Materials and labor once purchased and used as a part of a system of water-works are no longer commodities in the market with value fixed by the rise and fall in prices of new materials and labor. At a certain cost these things have already entered into the creation of a system and are devoted to a fixed and permanent use; and why should one adopt as a starting point in the determination of structural values a standard subject to daily and almost unaccountable market variations in preference to a standard that actual accomplishment has unalterably fixed. There appears no good reason for so doing so long as the statements of actual cost are worthy of credence and their reasonableness unimpeached.

If, on the other hand, the rate fixing powers have made such liberal provision in the revenue as to permit in addition to adequate returns upon the property value the making of ample provision for safeguarding the property against loss through falling prices of materials and labor, or the deterioration of perishable materials, or the abandonments incident to changing conditions, as well as other possible causes of loss, then cost becomes of lesser importance in determining a just value of all structural works, and corresponding greater weight may attach to estimated cost of works of duplication or substitutional equivalent without working injustice.

In determining the actual cost to a company of its plant recourse can usually be had to its book record. The reliability of such record can by a competent engineer generally be determined by a study of the property. Not with exactness, of course, but within such reasonable limits as is worth while attempting in arriving at a final determination of present value, involving as it does so many broad considerations.

An important question, however, relates to the disposition of losses early in the history of the plant, arising from a lack of revenue, and their relation to cost and value.

The correctness of the policy of adding annual deficiencies in the operating of a plant to investment in determining the cost of a property to its stockholders as contrasted with other forms of investment paying current rates of interest is, of course, admissible. That such a course throws any light upon the question of value of the property is not so clear and needs amplification.

In ordinary competitive enterprises such a computation would indicate nothing more than the loss which had been sustained in comparison with more remunerative forms of investment. If, however, as in the case of almost all water-works, the enterprise be of a character which does not usually, and therefore is not expected to yield adequate returns for some years after its inception, making the anticipation of this condition necessary to the successful financing of the enterprise and its establishment on a firm basis, such early losses may be charged to investment and become a measure of the money value of that intangible though none the less real asset known as "established business" or quality of being a "going concern," or possessing the ability to earn an adequate revenue, which the courts have recognized in certain important cases.

With a meritorious enterprise there should, of course, come a time in a reasonable period when the earnings become sufficient to pay a proper return upon the investment inclusive of such early losses, otherwise it must be classed as unprofitable and its value be less than its cost.

In the case of a public utility limited as to its possible earnings by an extraneous rate fixing body unnecessarily to a sum less than sufficient to constitute a proper return upon the investment, it would appear that redress from this condition should be sought in the courts rather than by charging such losses to investment for a long period of years.

Save in so far, therefore, as these losses may be said to be a measure of the cost of establishing the business, they do not of themselves unsupported by other considerations constitute a basis of value; and the most that can be claimed for them on their own account is that such losses from lack of revenue during the early history constitute the cost of and are, therefore, a measure of the value of that asset known as "established business."

Losses from abandoned structures from lack of sufficient revenue for refunding the money thus invested must be regarded as in much the same position as losses from inadequate interest returns from the same cause.

Such losses will, however, seldom accrue to the cost of establishing the business, for this should ordinarily be accomplished within the life of all structures of importance.

It is true that failure on the part of rate fixing powers to afford this revenue when it could reasonably be allowed without imposing excessive rates does a gross injustice to a water company, which should not be tolerated, but such structures are permitted to long pass out of use without enforcing compensation for them they cannot be said to still have value save possibly as a moral claim.

THE DEGREE OF PRUDENCE AND ENGINEERING SKILL EXERCISED IN THE ACQUISITION OF THE WATER-WORKS PROPERTY AND THEIR RELATION TO VALUE.—In considering this subject it is necessary to ascertain:

(a) Whether no greater price has been paid for land and water rights than was reasonably necessary.

(b) Whether the structural works have been designed and built on sound engineering lines and with a proper regard for a wise economy.

The first calls for no special comment. In passing on the second it must be remembered that no small part of engineering is the adapting of means to ends, that there are almost no established standards of design, that no two men will ever plan works along identical lines, and that a wide range of liberty of choice must be accorded the engineer.

The appraiser has a right to expect and demand that the works shall have proven reasonably successful considering all the conditions which have influenced or controlled their design and construction, with average practice as his standard rather than his own personal preference. Beyond this he should be sparing of criticism. Unqualified failures due to inexcusable ignorance or bad judgment must lead to rejection in determining value, but the appraiser will often find difficulty in determining in his own mind where to draw the line between what is excusable and what inexcusable. If he is a man of wide experience he is least likely to indulge in hasty or harsh condemnations, realizing that engineering is very far from being an exact science; that to some extent it will always be the unexpected that happens; that defects are more easily discoverable under the test of actual trial; and that criticism is far easier than creation.

THE PAST POLICY OF THE RATE FIXING AUTHORITIES.—Depreciation as ordinarily applied to water-works results either from the wear and tear incident to use and exposure to the elements, or from enforced abandonment on the score of economy or of changed conditions.

For example of the first, iron pipes are gradually rendered useless by corrosion until renewal becomes necessary; for example of the second, pumping stations may have to be abandoned because the water supply has become of uncertain purity, or because increased consumption or later and better designed machinery renders the old unsatisfactory on the score of economy, even though such machinery may still be in as good condition as it ever was.

In any event depreciation represents a shrinkage or dimunition of tangible property value which must be written off to expense as a part of the cost of maintaining the service and which must be paid for out of the revenues if the capital so invested is to be preserved unimpaired.

There are two ways by which this may be done: (a) By the establishment of a fund out of which all renewals and losses from abandonments are made good, the said fund being maintained by uniform periodical contributions from the revenues; or (b) by meeting the actual expense of renewals and abandonments each year out of the revenues of the same or succeeding year.

Either policy preserves intact the invested capital and charges depreciation where it belongs as an item of expense.

The former method is for some reasons to be preferred, chiefly because it equalizes this item one year with another, thus permitting a more uniform water rate, and because it is the practice almost always followed though in an indirect way. For most water-works unless prevented by restrictive legislation make provision in their revenues each year for the redemption of a portion of their bonded indebtedness, and under all ordinary conditions such provision exceeds in amount and renders unnecessary the making of any other provision for depreciation.

It scarcely need be pointed out that a policy of making no allowance at all or of making insufficient allowance for depreciation, and then discarding the cost of the structures after abandonment in the determination of value for rate fixing purposes, is nothing else than confiscation, which, by a process of gradual absorption, tends to ultimately consume all the capital invested in such structures, with the result of having afforded water service to the consumers at just that much less than cost to the company.

The power that fixes the revenue determines the method by which depreciation shall be cared for, if cared for at all. If that power has made possible the provision of a fund for this purpose, but has, on the other hand, established the policy of allowing depreciation only as the renewals are actually made, the policy should be pursued to its logical and right conclusion and no structures when abandoned be disallowed in whole or in part in determining value until its cost shall have been in the same proportion refunded from the revenue.

tures which have passed out of existence or which ger serve a useful purpose may not be included r the matter of their depreciation has in the past ightly or wrongly dealt with.

tures which are still useful should not be depre- in determining value without provision being made revenues for refunding their cost.

n a charge is properly made against the otherwise of a property because of structural depreciation, the t of that charge should not be greater than the es- d present value of an interest-bearing sinking fund contributed to annually during the average useful nce of the plant will equal in amount the investment e various parts at the end of their usefulness.

it is the duty of a water company to use reasonable nce to secure for the future as well as for the pres- an abundant water supply, a proposition seemingly nd question; and if this can be accomplished most iently by the acquisition of properties in advance of r actual requirements for the supplying of water, it ainly seems that such property before its development n the true sense in use, since it has been purchased and devoted to that purpose in recognition of the com- y's duty to the public.

If it has been the settled policy to include such prop- ties, then the investor being relieved from risk and loss interest in such investments might in fairness well feel that the public had acquired such rights as would war- nt his accepting a lower interest return, or its equiva- nt, on the value of such property after it finally comes into actual use than otherwise. In other words actual cost would then have greater weight in determining value for rate fixing purposes than the cost of an equivalent property.

If, on the other hand, it has been the established policy to exclude all property not actually employed for the sup- plying of water in determining value for rate fixing pur- poses, thus compelling the water company in the discharge of its duty to carry such properties it may be for years, at its own risk, then surely this original cost has much less weight in determining their value when they do come into actual use—unless, indeed, cost be made to include also the losses of interest due to their retention—and the cost of other equivalent properties becomes of correspond- ingly greater importance in determining value.

It, therefore, logically appears that lands and water rights in general which of necessity are in the main se- cured and held long periods in advance of their actual use should in the determination of their values after they have been brought into use have considered their cost in- clusive of loss of interest, and also the cost of acquiring a substitutional equivalent. The latter should establish the maximum and the former the minimum when below the latter, provided that the total valuation of the entire water-works property does not exceed the value of the service rendered. Should cost with interest prove greater than a substitutional equivalent, it demonstrates impru- dence for which the consumer should not be held respon- sible.

THE ESTIMATED COST OF THE REDUPLICATION OF THE EXISTING STRUCTURAL WORKS AND ITS RELATION TO COST AND VALUE OF THE EXISTING PLANT.—Previously herein has been pointed out the grave objections to adopting the theory suggested by this head- ing as the sole or even paramount consideration in the determination of value of existing structures when they are sought to be valued simply as structures separately and independent of their relation to the system as a whole.

Nevertheless, it is proper to make such inquiry even though the actual cost of the existing structures may be known with certainty, for the answers will usually be serviceable in determining the degree of prudence and economic skill which has been exercised in the construc- tion of the existing works. In other words, the answer to the query goes rather to the question of prudence in the expenditures actually made than to the value of the structural works in question. This is particularly true where the rate-fixing authorities have pursued the policy of not allowing a revenue sufficient for safeguarding the actual investment in structures against subsequent falling prices and corresponding lesser cost of their reduplication at a later date.

Works of the magnitude here considered never are and cannot be constructed as of any particular date or any particular year. In determining, therefore, the probable cost of their reduplication it is necessary to forecast the prices of materials and labor likely to prevail at least during such period of time as would be necessary to carry out the assumed program. To make such forecast one cannot usually do better than to judge the future by the past and assume as a basis the general average of condi- tions which have prevailed for a period of years.

THE ESTIMATED COST OF THE CONSTRUCTION OF SUBSTITUTIONAL WORKS AND ITS RELATION TO VALUE OF THE EXISTING PLANT.—The estimated cost of constructing independent substitutional works has, for reasons already fully set forth, little relation to the actual value of existing structures save as such studies may throw light upon the question of the wisdom of the adopted plans after which the works have been built.

Unless such estimates can prove the existence of gross and inexcusable error in the adopted plans, they are not entitled to great weight in determining the value of exist- ing structures.

In determining the value, however, of any combination of real estate and water rights which have together been made a source of water supply for which there exists a demand, the estimated cost of creating an equivalent from the next most available source becomes at least one measure within limits of the present value of the properties and rights already acquired and in use.

This proposition rests upon the theory that since such enhancement of value due to general community growth and prosperity, to which a water company so largely con- tributes, is in the case of individuals or private enterprises always regarded as legitimate gain there seems absolutely no reason why the properties of a water corporation de- voted by process of law to the public use for no more than a fair annual return upon its value should not share in such enhancement.

The writer has pointed out that this is entitled to spe- cial weight in determining the value of water producing properties when companies are compelled to carry them at their own risk and expense until such time as they are actually required for use.

APPRECIATION OF REAL ESTATE AND WATER PRODUCING PROPERTIES AND ITS RELATION TO VALUE.—It seems clear that any determination of present value, if cost be used as the starting point, should be in- fluenced by the appreciation if any that has taken place in real estate, water rights, and such like properties since their acquisition by the owners of the works.

It not infrequently happens, especially in the semi-arid sections of the country, that water rights and privileges and real estate so situated as to afford unusual natural op- portunities for affording run-off and storage facilities of an exceptional character, though secured at comparatively small expense, through increased demand due to increase in population become in time of greatly increased value.

Inasmuch as such enhancement of values is always re- garded in the case of private enterprise as legitimate gain, and particularly since general prosperity which creates such enhancement is as largely fostered by a system of water-works as by any other agency, there seems no valid reason why such increase of values above original cost should not accrue within limits to the advantage of the water company. The actual determination of the present value of such assets must, of course, take into account the general scheme of which they form integral parts, and the final result as a whole to which they contribute. No piece of property, however difficult it be to find a satisfactory measure of its value, can be counted as worth less than the cost of other as favorably situated tracts.

If this principle is applied to the combination of prop- erties which, because of their having been brought to- gether, have made possible the delivery for possibly all time of a suitable volume of potable water, then logically the amount of increase in value of such property or its present value would be sought in the cost of developing or otherwise obtaining an equally abundant and equally marketable supply from the next most available source. This, then, is the justification for using the probable cost of a substitutional equivalent as at least strongly indica- tive of value. This method will usually have its chief application and will most affect the final result in the case of those properties used for creating and safeguarding the sources of water supply as distinct from the distribut- ing system, in those regions of the West where the wa- ter supply is the great problem. On the other hand, where the community has at hand inexhaustible sources of sup- ply free to any one at the cost of taking, water rights may have no value and no increase in excess of cost then becomes ordinarily possible.

HAS THE FRANCHISE ANY VALUE?—The answer to this question depends upon what is meant by franchise. If a concern is actually earning revenue in excess of an amount sufficient to meet all costs of production including a proper return upon the value of the property employed, it has become a very common practice to credit such sur- plus earnings to franchise. It cannot be denied that un- der such conditions, by whatever name it may be called, this ability to earn a large surplus, when it may be ex- ercised, constitutes an important element of value.

It appears, however, that the creation of any earning power directly attributable to franchise under this defini- tion, and the consequent creation for it of real value where it has cost nothing, presupposes the entire absence of reg- ulation of rates on the part of government for the purpose of securing water service at no greater cost to the con- sumers than is consistent with fairness to the water com- pany. In other words, franchise if it has cost nothing is not necessarily an element of value upon which any rev- enue need in fairness be allowed by rate fixing author- ities. Indeed, the very purpose of the law apparently is to prevent such excess earnings as are here assumed to give value to the franchise.

If there are no legal restrictions, and a water company is allowed to collect such rates as seem to it alone expe- dient, it may easily be imagined that its earnings might in many cases be greatly in excess of what would net it a very reasonable or even liberal return upon the otherwise value of its property, no matter by what rational method such value were determined.

Again, when water companies have by wise foresight and prudent expenditures acquired properties, such, for in- stance, as lands and water rights, which, by reason of their special adaptation to their purpose, cannot be dis- pensed with without securing other properties productive of equivalent results at a cost materially in excess of the investments actually made, such enhancements of value have sometimes been credited to franchise.

This element of value has already been pointed out to be a very real asset; but it stands in a class by itself. To term it franchise value seems a misnomer since it repre- sents real value wholly independent of the franchise.

Again, the fact that a property possessed of and actually doing a large business capable of affording a sufficient revenue is worth more than a similar property without such business, has sometimes been termed franchise value.

This, too, while doubtless a real asset, is better classed as "established business" and will later be again referred to.

The writer is, therefore, of the opinion that the first before-mentioned view of what constitutes franchise value is the correct one; that every other element of real value is more properly classified elsewhere; and that under wisely drawn legal provision for the regulation of rates no value need attach to franchise either for purposes of taxation or revenue.

DOES ANY SPECIAL VALUE ATTACH TO THE FACT THAT A COMPANY HAS AN ESTABLISHED BUSINESS?—Mention has already been made of this element of value. It has been pointed out that a system of works already possessed of sufficient business to make the property a profitable investment is worth more than a similar prop- erty without a revenue.

That an established business constitutes a very real asset would seem to be beyond dispute, but the money measure of its value is so difficult of determination that it has at times compelled resort to mere arbitrary opinion. Such a procedure is always to be avoided if a logical standard can be found.

It does not appear that such a standard is wanting where proper accounting has been employed; and its rea- sonableness lies in the fact that it is rooted in the ne- cessities of water-works construction and growth as dem- onstrated by general experience.

This measure is found in the actual cost of establishing the business as ascertained by the losses during the early history of the plant arising from the want of a sufficient revenue to pay at least current rates of interest on the necessary investments. Reference has already been made briefly to this subject, but it is worthy a little further amplification here even at the rick of some repetition.

The building of water-works suited to prevailing needs with liberal allowance for future increase is a work of ne- cessity for any modern city, a work which, especially in the regions of sparse rainfall, must after the first nucleus is formed precede rather than follow growth in population.

A suitable water service must be obtained regardless of the magnitude of the necessary cost.

Because of these facts it almost invariably happens where local conditions render necessary heavy initial cap- ital outlays, that to some extent the future must be dis- counted in the early financing of the enterprise. In other words, the limited number of rate payers makes it im- possible for the enterprise to pay adequate returns on the investment until the population and business industry, increasing under the stimulus of an abundant water sup- ply and other causes, make possible an adequate revenue.

What is to be the return for this unavoidable additional source of expenditure in the establishing of a sufficient business? Its result is the creation of this asset of "es- tablished business" and the attendant expense is an actual measure of what it has cost to create it by the only means by which such an element of water-works value can be created. Cost is therefore a rational measure of the value of this element "established business."

THE VALUE OF THE SERVICE RENDERED TO THE PUBLIC AND THE LIMITATIONS IT IMPOSES UPON VALUE.—The value of an established water-works property, no matter how great may have been its cost nor how great a sum would be required to secure a substitu- tional equivalent, cannot in the final analysis be more for rate fixing purposes than the capitalization of its greatest possible net earnings without restriction as to charges. In other words the worth of the service to the consumers will always fix a maximum beyond which no theory of value, however plausible it may appear, can be followed.

What is the worth of the service to the consumers and how may it limit the possible revenue, and thus limit the value of the water-works property?

(a) The service is not worth more to any consumer than it will cost him individually to secure an equivalent by pumping out of a well or from some other available source, if there be any; for if the rate charged exceeds this amount many will utilize such source in preference, with corresponding loss of revenue to the water company. The same holds good for all consumers collectively save that in such capacity they may be expected to regard the public welfare as well as that of the individual.

(b) If there is no other possible substitutional supply, thus placing the water company in the position of having an absolute monopoly, still the value of the service ren- dered cannot be worth more than the consumer can af-

ford to pay interest upon, without impairing the general prosperity and checking municipal growth.

To illustrate the above truths: If a water company were wholly unrestricted by any governmental agency in determining the amount of its charges, it would be folly for it to impose rates so high, no matter how great its necessary investment, as to invite destructive competition; and if no competition were possible it would be just as foolish for it to injure its present as well as its future business by imposing rates so high as to check general prosperity and retard municipal growth. A wise policy and the one calculated to derive in the long run the greatest possible returns would always seek to keep well within these limits; and keeping within these limits, the property could not for rate fixing have a greater value than the revenue then received could support.

If the investment of the water company should prove in the long run greater than the value thus justified by the permissible rates, the loss is chargeable to bad judgment on the part of the investors and they should not be heard to complain.

When one attempts an inquiry as to the value of the service rendered in the specific case of any city he finds himself, however, without any standards of exact comparison. Water rates charged in different places are indicative of general practice, but each is determined by widely varying local conditions and none may answer the question directly as to what is the maximum revenue that those local conditions would if necessary warrant. If, however, the rates in question are ascertained by comparison to be materially less than have been successfully imposed without evil results in other cities of comparable wealth and general prosperity, it may be inferred that the application of similar rates would in the case in hand be a safe procedure.

Again, if property improved and unimproved is enhancing rapidly in value it is evident that the imposing, if need be, upon it of an increased cost of water service would accomplish no worse result than to divide the so-called "unearned increment" due to general increase in population in some proportion between water-works and real property.

This phase of the subject then deals with the total gross revenues which the company should be allowed to collect, wholly regardless of the magnitude of its actual investment. Its application therefore requires the study of general taxation as well as that imposed upon the company, the amount of revenue paid the company in compensation for public service, the cost to the company of operating and maintaining its works, the provision, if any, which should be made annually for liquidating investments in perishable structures or others which ultimately require abandonment, and the rate of interest which the property is entitled to earn over and above all expenses.

While only general conclusions can be drawn from so complex a study, they can, with the exercise of care, be made sufficient to establish the limitations sought with a degree of accuracy suited to the demands of substantial justice.

FINAL SUMMARIZING OF CONCLUSIONS AND DETERMINATION OF PRESENT VALUE.—Having considered the various hereinbefore enumerated factors likely to influence the value of any property under consideration, and having summarized the results, it will remain to determine the varying degrees of importance and weight to attach to each, and to decide in view of all the attendant circumstances what the amount is upon which the water company is entitled to receive a suitable return.

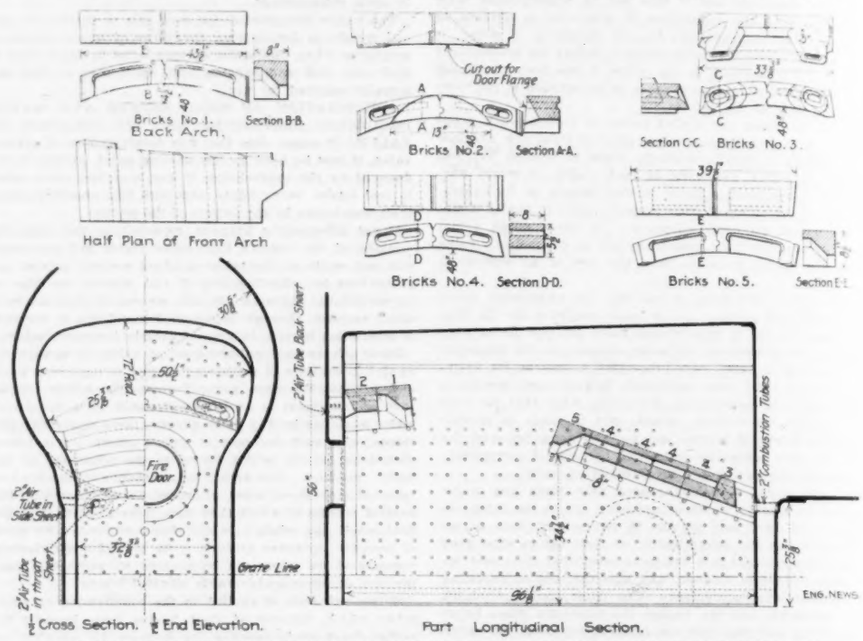
As has been stated at the beginning of this paper this final solution can never be reduced to a mathematical formula applicable to all cases. The before suggested inquiry will have established approximate limitations both as to maximum and minimum, but there will even then usually be found remaining quite a wide intervening field for the exercise of individual discretion.

That the final result will so largely depend upon the personal equation does not of necessity detract from its worth. It only shows the greatness of the problem which requires for its solution the exercise of faculties higher than the application of mere formula and mere routine, faculties which are rooted in laborious thought, in ripe experience, in moral worth.

Justice in dealing with such highly abstract questions calls only for the best that can be had and nothing less; and the best will always be found sufficient for its ends, for this it is which determines our highest natural sense of justice itself, upon which all law must finally rest.

HOLLOW FIREBRICK ARCH FOR LOCOMOTIVES ON CHICAGO & NORTHWESTERN RAILWAY.

The Chicago & Northwestern Ry. is equipping a number of its switching and suburban locomotives in the Chicago district with a special design of firebrick arch for the purpose of preventing smoke, and the construction is shown in the accompanying cut. The arch is in two parts, the larger one at the front end, and the shorter one over the fire door; they are estimated to weigh 538 lbs. and 187 lbs., respectively. The arch blocks are hollow, pierced with oval openings which connect with 2-in. air tubes passing through the water spaces, the cold air thus admitted being heated as it passes through the hollow arch. At the end of each arch, the blocks are so formed as to throw the current of air downward. Templets are used to lay out the locations of the combustion tubes, and the supporting studs for the arch bricks. After the bricks have been set, a tight joint is made with the combustion tubes by means of fire clay, and the joints are plastered over. This smoke preventing device, known as the Wade-Nicholson arch, was invented and patented by two employees of the Chicago & Northwestern Ry., and is handled by the American Locomotive Equipment Co., of Chicago. For drawings and information we are indebted to Mr. R. Quayle, Superintendent of Motive Power and Machinery of the Chicago & Northwestern Ry.



HOLLOW FIREBRICK ARCH FOR LOCOMOTIVES: CHICAGO & NORTHWESTERN RY.

While some fuel economy must result from the more complete combustion and the prevention of the loss of fuel in the shape of smoke, there is little appreciable saving in service. Mr. Quayle points out, however, that it is difficult to find fuel economy on a locomotive, because when an engine is found able to do a little better work it is compelled to do a little more work, and that of course prevents any showing of economy. The life of this brick is about three times that of the ordinary brick which has formerly been used.

CALCIUM CARBIDE AND ACETYLENE.

A comprehensive paper with the foregoing title was read before the Western Gas Light Association at Chicago, in May, 1905, by Mr. J. B. Morehead, of Chicago, the discoverer of calcium carbide. Much of the information given in the paper has already been widely published, but some new facts, or old ones worth repeating, may well be presented here.* In his opening sentence Mr. Morehead defined carbide as follows:

> By a carbide is understood a combination of a metal, or of an alkaline earth and carbon. The carbides are not to be confounded with the much more numerous family of carbonates, which contain oxygen in addition to the above and possess entirely different physical and chemical characteristics. Carbides do not exist in nature, but it is probable that those of almost all of the metals can be formed artificially by means of extreme heats, etc. Carbides of most of the metals have been produced and studied, but only two are of any commercial value, namely: Carbide of silicon, which is sold under the trade name of carborundum, and is used as an abrasive, and carbide of calcium, which is sold as such and used as a source for the commercial production of acetylene.

The author next described how calcium carbide was discovered on May 4, 1892, at the plant of the Wilson Aluminum Co., in North Carolina, during experiments designed to perfect the manufacture of aluminum. This carbide and its manufacture and also the generation and use of acetylene were described as follows (we have made some omissions):

> Calcium carbide is a crystalline body, hard, brittle, varying in color from almost black to brick red. Its specific gravity is 2.26. A cubic foot of crushed carbide weighs 138 lbs., and in weight, color and most of its physical characteristics is about like granite. If broken the fracture shows a handsome, bluish purple iridescence and the crystals are apt to be quite large.
>
> Calcium carbide is insoluble in most acids and in alkalies, it is non-inflammable, infusible, non-explosive, unaffected by jars, concussions or time, and, except for the property of giving off acetylene when brought in contact with water, it is an absolutely inert and stable body. The transportation companies afford it the same classifi-

*The paper in full may be found in "The American Gas Light Journal" for July 10, 1905.

tion for shipment that is given nails or spikes in kegs. Chemically it is described by the formula CaC_2, and has 62½% of calcium and 37½% of carbon. It is made by the reduction and combination in an electric arc furnace of a mixture of finely pulverized and intimately mixed calcium oxide or quicklime and carbon in the shape of coke. There is no adequate way of measuring the temperature necessary for the production of calcium carbide, and any estimate is merely approximate, but it is calculated to be from 5,000 to 8,000° F.

When we consider that the arc light people and the other electrical users employ carbon for their electrodes, because it is the only substance which will stand the extreme temperatures, and that the carbide makers themselves and also the carborundum people use carbon electrodes for the same reason, and, further that crucibles of lime are used in gold and silver assaying, and for the pencils of the Drummond oxygen-hydrogen light on account of its extremely high fusing point, and then remember that carbide making is a purely thermal reaction and that these two bodies which are about the most infusible substances known to science are mixed pure—without any flux whatever—and driven into unwilling combination by virtue of sheer force and violence of the temperatures obtainable only in the crater of an enormous electric arc, it will be appreciated that the temperatures required and attained in this process are something simply terrific. The furnaces employed from 250-350 electric power each and produce about one ton a day. The output is crushed to different sizes and packed at the rate of about 50 tons a day in the two factories, and it is sold for $70 per ton at the works.

There are a few chemical uses for calcium carbides, but up to the present time they are in the experimental stage, and it can safely be stated that the entire use for calcium carbide is for the production of acetylene.

Acetylene is a colorless and tasteless gas. When chemically pure it has a sweet, etheral odor, but in the commercial form it carries small percentages of phosphoreted and sulphureted hydrogen which give it a strong pungent odor. One cubic foot of acetylene weighs .069 lbs.; 31.85 cu. ft. of acetylene weigh 1 lb. One cubic foot requires 11.91 cu. ft. of air for its complete combustion. Acetylene has a gravity of .92 (air being 1) which is very nearly as heavy as air.

Acetylene contains 12 parts carbon and 1 part hydrogen,

carbon and 7.7% of hydrogen. It is the nearest to gaseous carbon, and it possesses a higher candle-power than any other substance which is known or utilized as possible in chemistry. It is an endothermic combination and possesses the extraordinary candle power of 2,500 candles for 5 cu. ft. It is soluble in its own volume of water, and in varying proportions in ether, alcohol and turpentine and to a very large extent in acetone. It liquefies under a pressure of 700 lbs. per sq. in. at a temperature of 70° F. The pressure necessary for liquefaction varies directly with the temperature up to 98°, which is the critical temperature for acetylene, beyond which no temperature it is impossible to liquefy the gas at any pressure.

When calcium carbide is brought into contact with water the calcium of the carbide, which possesses a greater affinity for oxygen than the hydrogen which forms one-ninth of the water does, robs the hydrogen of its oxygen and forms lime and thus sets the hydrogen free. At the same time that the calcium of the carbide combines with the oxygen of the water, it liberates its loosely held carbon, and this carbon of the carbide and the hydrogen of the water being nascent, and having nothing else with which to combine, unite and form acetylene. The primary reaction is the formation of lime with the formation of acetylene incidental, but as wheat may sometimes be threshed for the chaff, so in this instance the by-product is of value and is saved, while the body, which furnished the energy for the reaction, is thrown away in the water in the form of slag.

Sixty-four pounds of calcium carbide combine with 36 lbs. of water and produce 26 lbs. of acetylene and 17 lbs. of residue. The residue is very pure, slacked lime, and may be used for whitewashing, mortor making, fertilizing, disinfecting, or any other purpose for which lime is ordinarily employed.

Chemically pure calcium carbide will yield at 70° F. and 30 ins. mercury, 5.83 cu. ft. acetylene per pound of carbide. Commercially pure carbide is guaranteed to yield 5 cu. ft. of acetylene per pound and usually exceeds the guarantee by a few per cent.

The reaction between calcium carbide and water, and the subsequent slacking of the calcium oxide produced, give rise to considerable heat, which is the principal foe of the generator designer. This heat from one pound of chemically pure calcium carbide amounts to sufficient to raise the temperature of .49 of a gallon of water from the freezing point to the boiling point.

Owing to the extreme richness of acetylene, burners for its consumption are unique in design. They are built with a view to supplying an amount of air which with other gases would be in large excess. They are made by the employment of two Bunsens which inject air along with the gas, from which the streams of gas from the two arms enveloped in air impinge on each other and form the luminous part of the flame in the air, and of contact with any part of the burner.

There are two types of generators; one in which a varying quantity of water is dropped onto the carbide, the other in which the carbide is dropped into a large excess of water. The first class may be subdivided into the machines in which the carbide is dipped into the water and then withdrawn, or in which water is caused to flood a mass of carbide and then to recede. Owing to the large amount of heat generated by the reaction, and the susceptibility of the acetylene to heat, the first, or dry type, is confined to lamps and to small machines.

There are two ways of getting rid of this heat of generation, and the degree of success attained in a very large measure determines the success or failure of the generator.

The first is by dissipation into the surrounding air, and the second is by absorption in water. Dry machines depend upon the first principle; wet machines upon the second. A few small machines, such as bicycle and automobile lamps, etc., depend upon the first principle; all large machines upon the second. The underwriters require provision for one gallon of water for every pound of carbide, and as it requires only 0.56 lb., or a little over ½ pint of water for the chemical reaction, there is ample water left for the absorption of the heat, and the possibility of danger, or rather of annoyance and expense from overheating, may be considered as out of the question with any approved acetylene generator of the wet type now on the market.

Acetylene contains 1,685 B. T. U. per cubic foot as compared with 1,000 for natural gas and 600 for coal or water gas. And while the illuminating value of acetylene is from 10 to 15 times that of ordinary gas, excepting for small uses, acetylene is neither a power, a heat nor an enriching proposition.

At the present state of development of the acetylene industry, and of the art of calcium carbide manufacture, this gas will not compete with coal gas or water gas, or with electricity as supplied in our cities.

Acetylene may be stored under pressure for railway and other portable lighting, and it may be absorbed in acetone and used for the same purpose. It is so used under the first system in about 300 acres now being lighted under the well-known Pintsch system of gas storage. The second system is being experimented with and is making quite some headway.

For lighting towns too small for water or for coal gas, or for those parts of larger places not now reached by the regular mains, acetylene is very well worth the attention of the gas fraternity. Acetylene offers the one practicable and profitable method of lighting towns of less than from 3,000 to 4,000 inhabitants. That it is successful in lighting the smallest as well as the largest of these towns is shown by the fact that of the more than 200 acetylene plants now in operation, about 75% are in towns of between 500 and 2,500 population.

While automatic generators have been used for making and supplying gas to mains direct, the use of such method is not advisable for obvious reasons, and the largest and most successful systems of town lighting are those employing storage holders large enough to supply the maximum consumption of any 24 hours. The generator used by the United States Government at Fort Meyer, Va., and Chickamauga Park, Ga., two large acetylene systems, and by the majority of the largest town lighting plants in this country, is a heavy cast-iron and boiler plate apparatus which feeds a limited amount of carbide into an excess of water by means of a screw conveyor, the conveyor being driven either by hand or by a small water motor.

A feature that is unique in producing acetylene is that the cost is not dependent upon the quantity of gas generated, as no fuel or materials other than carbide and water are required. Acetylene may be produced in small quantities at quite as low a cost as it can be made in large volumes.

The growth of the acetylene town lighting plants has been phenomenal. In 1898 there were 4 plants; in 1899 there were 8; in 1900 there were 30; in 1901 there were 39; in 1902 there were 60; in 1904 there were 202, and since the beginning of the present year a number of new ones have been started.

In addition to the town lighting plants there are now in operation over 80,000 isolated plants supplying from 10 to 2,000 burners; there are bicycle and automobile plants without number, and there are several thousand table lamps supplying a magnificent reading light where it is not obtainable otherwise.

As to a supply of carbide, The Union Carbide Co. has two large works, one at Niagara Falls, N. Y., and one at Sault Ste. Marie, Mich.

A SUBMARINE ROCK EXCAVATOR.*

By Charles Graham Hepburn, Assoc. M. Inst. C. E.

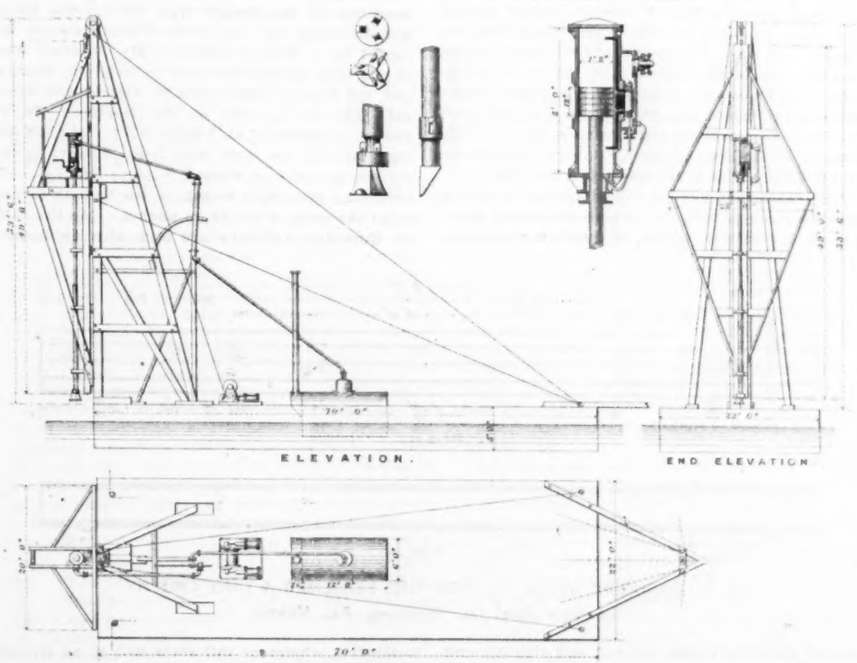
The apparatus described in this paper was designed and built by Messrs. R. M. Scott and A. Goodsir in Sydney, New South Wales, in 1897, for the purpose of enabling them to carry on wharf-building and contracts involving operation on submarine rock, in a more expeditious manner and at a lower cost than with the rock-breaking apparatus and methods then known.

Since that date the machine has been in continuous use in the harbor of Port Jackson, Sydney, for deepening various portions where a rock bottom exists, for drilling holes in rock for the reception of wharf piles, and for levelling rock for retaining-wall foundations. The surface left by the machine is clean and regular, and the excavation may be finished to a level or an inclined bed as may be necessary.

DESCRIPTION OF THE MACHINE.—The excavator consists primarily of a cutting or drilling tool connected directly to a piston reciprocating in a steam cylinder of considerable length, which is carried on a vertical slide or carrier, capable of vertical adjustment on a "tower" erected on a punt or other floating structure, Fig. 1.

With a piston rod of considerable weight reciprocating through a stroke of several feet, under the positive action of a piston acted on by steam, the work of breaking up large bodies of submerged rock is very speedily accomplished. For example, when the moving parts weigh about 3½ tons and the stroke of the piston is about 4 ft., it has been found that, making 60 strokes per minute, this apparatus will break more than 30 cu. yds. of hard submerged sandstone rock per day. The debris may be removed by dredging, or it may be found convenient to pulverize it in situ by means of a hammer head substituted for the chisel or cutter, and to raise the reduced material by means of a sand-pump.

The "tower" erected on the punt consists of two vertical timbers, each 12 ins. square in cross-section, set 1 ft. apart and braced with diagonal struts and steel wire guys. The carrier which slides vertically upon the face of the "tower," and which has its movement controlled by a steam winch, is formed of two vertical timbers, each 12 ins. square in cross-section, and a framing of 12 × 6-in. timbers bolted together so as to provide a rigid structure. The carrier is secured from transverse movement on the tower by a T-shaped guide or retaining piece bolted to its vertical timbers and sliding between the two upright timbers of the tower. The flanged head of the T-piece bears against the rear of these timbers, to prevent the carrier from surging outwards. The carrier is provided with a shelter for the steam cylinder and the operator. The cylinder, which is 14 ins. in diameter and 5 ft. in length, is bolted securely to the carrier. The piston rod is 6 ins. in diameter at its top end, increasing to 7½ ins. in diameter at the lower end, and is guided by three bearings. The tool or chisel used for excavation or drilling is secured to the end of the piston rod by means of a cotter. The tools used vary with the particular class of work to be done; thus, when a hole is to be drilled in rock to receive a pile, the drill head shown in Fig. 2 is used, whereas in other classes of work the chisel shown in Fig. 3 is substituted. The drill head is formed of three drills forged from a steel bar 6 × 4 ins. in cross-section. The outer end of each drill is forged out to provide clearance by swaging both sides of its lower end, as shown in Fig. 2.



A SUBMARINE ROCK EXCAVATOR.

Steam is conveyed from the boiler to the cylinder by means of a 4-in. steam pipe, trunnioned at the joints to permit of vertical movement. One of the pipe-lengths is guided by a quadrant piece and is reinforced by timber bolted to the pipe, which bears against the quadrant.

MODE OF OPERATION.—The punt having been moored above the site to be operated upon, the sliding carrier is

*From Proceedings, Institution of Civil Engineers, Vol. CLIX., Part I. (1904-5).

lowered until the tool on the end of the piston rod has touched the rock bottom and the piston is just above the lower port of the cylinder. The slide valve is operated by hand, similarly to that of a steam hammer. As the drill sinks into the rock, the carrier is constantly lowered during the operation of drilling, so that the full stroke may be obtained, until the hole has been sunk to the requisite depth. To obviate the danger of the piston striking the bottom of the cylinder with sufficient force to cause injury to the cover, a supplementary steam pipe, taking its supply from the valve casing, is led into the bottom of the cylinder. This arrangement insures a constant supply of steam at boiler pressure on the lower side of the piston, acting on it as a brake or buffer on its descent, the piston driving the steam back through the pipe into the valve casing. A further precaution, to prevent accident, is taken by forming the steam ports in the cylinder at some distance from the end, thereby allowing the piston to shut off the exhaust at a point where the imprisoned steam can also co-act as a buffer, Fig. 4.

In every-day practice it has been found that with careful handling of the valve these safeguards are sufficient to obviate any damage to the cylinder.

Messrs. Scott and Goodsir report that although the apparatus has now been in constant use for a period of six years, no renewal of the cylinder, cylinder covers, piston rod or steam pipes have been necessary, the apparatus as installed in the first instance being still in perfect working order. The first contract upon which this rock breaker was employed was that of deepening the harbor at the Sydney Harbor Colliery wharf, at Balmain. During the several months in which it was at work on this, on an average 30 cu. yds. of rock were removed per day. This work, which extended over a large uneven area, was finished to a level bottom. The apparatus has also done a very large amount of work in rockboring for wharf piles. Its speed naturally depends upon the hardness of the rock upon which it is operating; in dealing with hard freestone, a hole 18 ins. in diameter and 5 ft. in depth can be drilled in less than 10 minutes. In softer rock the speed is considerably greater. A necessary adjunct to the submarine rock breaker is a force pump, fitted with a hydraulic hose and nozzle, to scour the debris from the drilled holes.

THE CARNEGIE STEEL TIE.

The engineers of the Carnegie Steel Co., of Pittsburg, have for some years past been investigating the use of steel ties with a view to the design of a rolled tie which would be satisfactory and successful in service and would afford business for the company's mills. As a result of these investigations a special I-beam section has been adopted, having a very broad bottom flange. It was considered that this section would combine ample bearing surface, the greatest rigidity and transverse strength for a given weight of metal, sufficient area for the rail seat, and good facilities for bedding and tamping the tie. The original design was by Mr. C. Buhrer, Roadmaster of the Lake Shore & Michigan Southern Ry.

The fastenings are clips held by bolts passing through the top flange. Where automatic block signals are in use, plates of insulating material can be placed between the rail and the tie, and the bolts fitted with bushings and washers of similar material. About 30,000 of these ties are now in use; 20,000 of these are on the Union Ry. (Pittsburg) and around the company's works; the others are on the New York Central Ry., Bessemer & Lake Erie Ry., Lake Shore & Michigan Southern Ry., Pennsylvania Lines, Duluth & Iron Range Ry., and the street railways of the Pittsburg Ry. Co. In addition to these, the company is now filling an order for 25,000 ties for the Bessemer & Lake Erie Ry.

The accompanying cuts show the ties and fastenings as now being made for the Bessemer & Lake Erie Ry. The tie, Figs. 1 and 2, is 8 ft. 6 ins. long, 5½ ins. deep, 4½ ins. wide on top and 8 ins. wide on the base, with a thickness of ¼-in. in the web, and weighing 19.36 lbs. per ft. Near each end the bottom flange is bent down to form an anchor lug to prevent lateral movement in the ballast. The fastenings, Fig. 3, consists of ¾-in. bolts, with heads formed to fit the sloping undersurface of the top flange; on these are slipped the rolled steel clips, which are secured by bolts with spring washers. The total weight is about 164.56 lbs. for the tie and 6 lbs. for the fastenings, or about 170 lbs. in all.

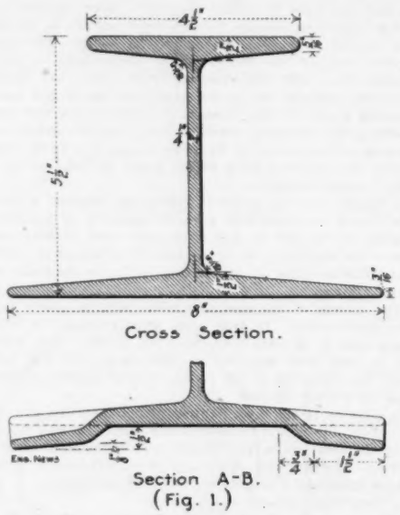


Fig. 2. Sections of Carnegie Steel Tie.

A majority of the steel ties which have been used are of the trough type (in varying forms and sections), but ties of an I-beam section designed by a French engineer, Mr. Severac, were at one time extensively used in Belgium, France, and the French possessions in Algeria and Senegal. The tie as used on the Northern Ry. of France consisted of an I-beam 8.2 ft. long, 4.8 ins. high and 3.2 ins. wide over both flanges; to the bottom flange was riveted a plate 9.6 ins. wide extending the whole length of the tie and turned up at the ends to act as an anchor. As the rails on European railways are laid with an inward inclination, chairs or rail seats had to be riveted to the top flange, making 26 rivets to each tie. These ties weighed 150 to 204 lbs. each, complete, and were spaced 34 ins. c. to c., or 24 ins. at the joints. Under heavy traffic on the Northern Ry. the rivets became loose, and the steel ties were replaced with creosoted beech ties having a life of about 27 years. In the Carnegie tie, all rivets and extra parts are done away with by the use of the special rolled section.

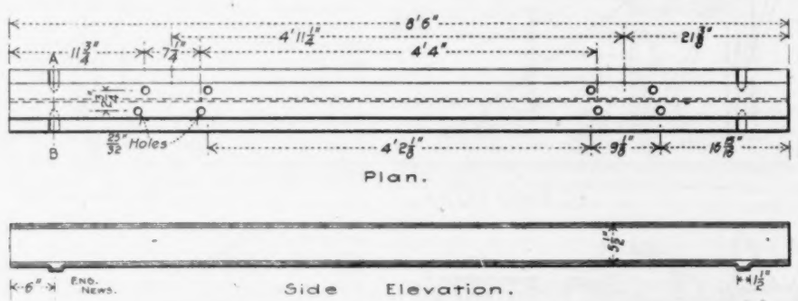


FIG. 1. CARNEGIE STEEL TIE FOR THE BESSEMER & LAKE ERIE RY.
Carnegie Steel Co., Pittsburg, Pa., Makers.

TRACTION ENGINE TRANSPORTATION is being [illegible] in Queensland, according to a report by Consular A[illegible] Weatherill, of Brisbane. Each train consists of an [illegible] gine and two cars and six trains are now in oper[illegible] and others have been ordered from England. The [illegible] lowing routes over which the trains are to be run [illegible] the extent of service: Yeulba to St. George, 129 m[illegible] St. George to Dalby, 304 miles; Warwick to Goondi[illegible] 120 miles; Miles to Taroom, 105 miles; Cunnamull[illegible] Thargomindah, 142 miles; Ilfracombe to Isisford, 65 m[illegible] Barcaldine to Muttaburra, 92 miles; Longreach to [illegible] ton, 125 miles. A service is also to be established [illegible] Grafton to Glen Innes, in New South Wales, a dis[illegible] of 60 miles. The engine and freight cars have wh[illegible] whose tires range from 6 to 12 ins. in width. The s[illegible] of the motors will be from 8 to 10 miles an hour, [illegible] they will have a load-hauling capacity of about 10 [illegible] The engines will run in pairs, one being equipped w[illegible]

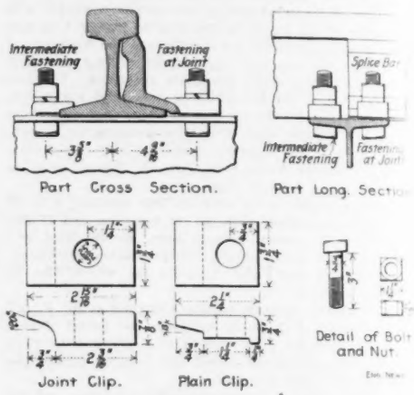


Fig. 3. Rail Fastenings for Carnegie Steel Tie: B. & L. E. Ry.

wood-sawing machinery for supplying fuel and also carrying a 30-ton steel hawser, fixed on an emergency drum, to assist in passing creeks and bad places on the road. The exhaust steam will pass into the return boiler tubes to extinguish sparks, so as to minimize risks of grass fires. The engines are strongly made and very compact. They are of the compound type, work with a pressure of 225 lbs. of steam, and are provided with filtering, suction, and other apparatus necessary for the class of work for which they are to be used. The gearing is in an inclosed oil tank, into which dust cannot penetrate. A derrick is also carried, so that, with the aid of the hawser before mentioned, heavy weights can be easily and quickly handled. Fuel in many districts can be easily obtained, but water, particularly during the summer months, will not be so accessible in the western country. On the routes mapped out, however, water stages of 20 miles have been arranged so that the services can be maintained in times of drought.

A RAILWAY CAR FERRY of an unusual character is operated between Peshtigo Harbor, Wis., and South Chicago, Ill., by the Wisconsin & Michigan Ry. and the Lake Michigan Car Ferry Transportation Co. Freight traffic connections with railways entering Chicago are made by water transportation, the cars being ferried over the distance of 240 miles by two barges 309 ft. long, 44 ft. wide and 10 ft. deep, hauled by two of the most powerful tow boats on the Great Lakes. Each barge has four tracks and can carry 26 cars, giving a loaded draft of 9 ft. The barges make six trips a week each way, and the round trip is made in about 51 hours, including the time for loading and unloading the barge.

A FORMAL PROTEST against even planning to discharge more sewage into New York Bay has been made, as set forth by the following resolution:

Whereas, At a regularly called meeting of the New York Bay Pollution Commission, held Aug. 1, 1905, it was brought to its attention that large sewerage systems are being planned to empty into the waters of New York Harbor or waters immediately tributary thereto, untreated sewage from non riparian communities it was

Resolved, That the Commission considers that formal protest should be made against the discharge into New York Bay or adjacent waters of any considerable amounts of untreated sewage from non riparian communities of either New York or New Jersey; and be it further

Resolved, That copies of these resolutions be transmitted to the officials or boards responsible for such contemplated sewerage improvements, and to the New York State Engineer and New York State Department of Health to the end that such contemplated systems may be provided with suitable purifying or disposal plants so as to save and harmless the waters of New York Harbor from further sewage contamination.

The members of the Commission are: Daniel Lo[illegible], Chairman, and Louis L. Tribus, M. Am. Soc. C. E. [illegible] Warren St., New York City), Secretary; Prof. O. H. [illegible] dreth, M. Am. Soc. C. E., of Schenectady; Myro[illegible] Falk, Jun. Am. Soc. C. E., and Geo. A. Soper, A[illegible] M. Am. Soc. C. E., both of New York City

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The current typhoid fever outbreaks reported from Worcester, Mass., some outlying parts of Greater New York, sections of Philadelphia not yet supplied with filtered water, Wilmington, Del., and Washington, D. C., are forerunners of the usual late summer and early fall prevalence of this water, milk, oyster and fly borne disease. Thus far, fortunately, these outbreaks are not of great magnitude and there is reason to suppose that they will not become notable epidemics. The occurrences suggest strict sanitary inspection and frequent analyses of all public water supplies liable to pollution; a most careful watch of the milk supply; the disinfection of all dejecta and urine from typhoid patients; abstention for some weeks longer, at least, from oysters and the like; the avoidance of water from private surface wells unless known to be above suspicion, and, where privies exist, the exclusion of flies from their contents and from houses as well. In addition there is the obvious suggestion of the provision of filtration works, particularly for surface water supplies. This is already being done for some of the communities named, while Health Commissioner Darlington has renewed the recommendations for filtration of the Croton supply made not long ago by the Commission on Additional Water Supply and later by the Aqueduct Commission. Doubtless the recently-organized New York Water Supply Commission, with its able engineering staff, will make this subject one of its earliest ones for prompt action.

A correspondent, whose letter we publish in another column, takes us to task for assuming, in our comments on yellow fever at New Orleans (Aug. 10) that "the yellow fever mosquito theory is a fact." We do not think many engineers who feel that they have studied the subject sufficiently to discuss it in a scientific spirit are so patience-tried as our correspondent would have us infer is his own case and therefore we venture to occupy still more of the space which he kindly terms "valuable" in order to present some remarks prompted by his letter. The mosquito theory of both yellow fever and malaria has been carefully investigated by a number of eminent scientists most of whom have been bacteriologists and public sanitarians rather than physicians. It is not this theory, but a clinging to the old-time theories of the transmission of malaria which is doing most injury to the South to-day. If we are not greatly mistaken, even more unreasonable and widely extended quarantines than the present ones prevailed during several southern yellow fever outbreaks occurring before the announcement of the mosquito theory.

It is for those who disbelieve and wish to disprove the mosquito theory to subject themselves to the bites of what our correspondent himself terms "yellow fever infected mosquitos," although he is arguing against the mosquito theory. Germs are still believed to be the cause of yellow fever; the mosquito instead of dirt or mere personal contact is merely the agent of transmission from one yellow fever victim to other possible victims.

No injustice has been done and no commercial or other injury is likely to be done civil engineers by the acceptance of the mosquito theory as applied to ridding Havana, Vera Cruz or any other city of yellow fever and cutting down if not eliminating malaria throughout the world. The new water supply, sewerage and drainage systems of New Orleans are made more and not less necessary by the mosquito theory. In fact, drainage work, that is land drainage, of great magnitude will demand the services of engineers for years to come in the efforts now being made and hereafter to be made to remove mosquito-breeding pest holes; but our bridge building correspondent need not fear that all the southern streams will be turned into dry land and bridges no longer required.

The rainy season at New Orleans this summer, combined with the trenching and other operations there, as mentioned by our correspondent, and also with the almost numberless cesspools and rain water cisterns in that sanitarily backward city, all tend to prove the correctness of the mosquito theory. Why the local officials and the New Orleans public in general did not foresee and act upon the dangerous conditions named, instead of waiting for the appearance of yellow fever, is one of the questions we had in mind when writing the note that appeared in our issue of Aug. 10, and to which our patience-tried Arkansas reader takes exception.

What is the value of a water-works plant for rate-fixing purposes, and how does that value differ from the value of the same plant when subject to municipal purchase? The first of these questions is discussed at length in an able paper by Mr. Arthur L. Adams, M. Am. Soc. C. E., reprinted elsewhere in this issue. The second question we submit to any of our readers who may feel inclined to discuss it.

Although Mr. Adams' paper deals specifically with water-works, many of the principles which he lays down are equally applicable to other public service industries. As the author suggests, engineers are in frequent requisition to aid in the settlement of public service rate questions, and will fail in both opportunity and duty if they do not materially influence wise legislation and sound court decisions.

The paper appears to be based on the assumption that a given water-works plant is operated many years before the city or other rate-fixing authority attempts to regulate the rates; or else that the rate-fixing basis has never been properly determined, or if determined, must be readjusted. It also seems to assume that the rate-fixing value of a water-works, under the circumstances just outlined, must be determined largely by indirection and by weighing and balancing various factors. Under the lax system of public control of franchise companies which generally prevails in this country, if indeed any control worthy the name is attempted outside of Massachusetts, the assumptions of the author are doubtless correct. But under a proper system of control it would be far less difficult and intricate than is indicated by Mr. Adams' lengthy and detailed analysis to determine the rate-fixing value of a water-works plants. Writing of actual rather than ideal condition, as he very properly should. Mr. Adams assumes that the municipality is virtually ignorant of the actual cost of the works to the company which is serving it, and of whether or not that cost has been wisely and, as concerns the city, fairly incurred. Such information every city should have regarding every public service company within its borders. To say this is, of course, no criticism of the excellent paper which Mr. Adams presented to the recent Pacific Coast Engineering Congress, a paper which we take pleasure in commending to our readers. The paper promises to be of particular value in California, where water-works rates are subject to yearly regulations by municipal authorities, and where hitherto much if not most of the regulation has been done in hap hazard fashion.

Among the many remarkable gaps in the literature of engineering economics none is more striking than the dearth of detailed information on the cost of bridge erecting. There are numerous text books and numberless articles on the design of bridges, but the data on labor costs are fragmentary and very unsatisfactory.

There are a number of articles to be found in which such statements as this appear: "The cost of erecting the steel work was 1¼ cts. per lb." General costs, like the above, are apt to be exceedingly misleading, which may account for the frequency of the erroneous assertion that all costs are misleading. To begin with, the reader needs to know what rates of wages were paid to the bridgemen before he can compare this "1¼ cts. per lb." with other cost figures. Next, he wants to know the organization of the bridge gang, the number of men and their several duties. With a small gang of low-priced men under a high-priced foreman, the cost of erecting may be unusually high. The same is true with a gang consisting entirely of skilled, high-priced workmen, with no common laborers as assistants in delivering and assembling materials. This necessity of recording the organization of the forces and the respective wages of the men is seldom appreciated by writers who have not had experience as contractors.

The cost of erecting a bridge may be divided into two parts: (1) falsework; (2) steel assembly plant and labor. The cost of falsework should never be lumped in with the cost of labor on the steel work, for it is the most variable item in the total cost of erecting a bridge. In a wooded country, and where streams are shallow, the cost of falsework for a bridge of 150-ft. span may be nominal; for a two-leg timber bent at each panel point can be cheaply made of round timber cut from the forest near by.

The cost of falsework should be recorded in three different ways: (1) The cost of materials and labor per 1,000 ft. B. M. of timber used and per lineal foot of piles driven; (2) total cost per lineal foot of bridge; (3) total cost per pound of steel in the bridge.

A bill of lumber and piles used in the falsework should accompany the cost record, and a statement should be made as to the salvage value of the lumber, if any. The cost of building a traveler and installing the plant for erecting a bridge should be recorded separately from the other items; for, on single, small spans, these items are often large in proportion to the actual cost of erecting the steel.

The manner of delivering the steel to the bridge men on the falsework should be described, as well as the methods used in erecting and riveting the steel. If possible, a record showing the percentage of lost time, and a statement as to the general efficiency of the force should be given.

What we desire to indicate by these brief hints is the possibility of preparing valuable articles on bridge erection. The subject seems old, but there are mines of knowledge on the economics of bridge building which await development. The subject is one of great simplicity compared with bridge foundation work, yet more valuable information exists in print to-day on the cost of bridge substructures than on bridge superstructures.

Let no young inspector of bridge work imagine that he can learn nothing after the first few days on the job. Every day can be made to add to his knowledge of how to handle, or how not to handle, men and materials. Let him trust nothing to memory, but make sketches of tools and appliances and methods used. Let him record each day's progress in such a manner that ten years later he can, by reading his notes, form a perfect mental picture of the work. It may be that he will never have occasion to direct the "swinging" of a bridge, but as a designer of economic bridges he can not help becoming more expert through his knowledge of field methods and field costs. If he wishes he may obtain an immediate financial recompense for his efforts by preparing an article describing in detail the methods and cost of erecting a bridge; for no such article has ever been written, so far as we know, and for years to come, if ever, engineering journals will not find the theme a hackneyed one.

AN INTERPRETATION OF RECENT TESTS ON THE FIRE RESISTANCE OF CONCRETE.

The career of cement concrete as a fireproofing material dates back scarcely more than ten years. Concrete had been used in fireproof construction previous to that time, but only in isolated cases and under special conditions; it had not gained a place among fireproofing materials which ranked it in any sense a competitor to brick and terra cotta. About 1896 the attempt was first made to introduce concrete floor construction for fireproof buildings in New York city. This attempt, as some of our readers will recall, was frowned upon by influential officials of the Building Department, whose hands were naturally upheld by the powerful business interests engaged in the manufacture and sale of burnt clay fireproofing materials. A bitter fight resulted. The New York Building Department inaugurated a series of fire and water tests of fireproof floors. Concrete floors and tile floors were tested separately and side by side, and the figures of these tests and their explanation and discussion filled columns of the engineering and architectural journals. The result of the battle was the withdrawal of the official ban on concrete not only in New York but practically all over the country. This result did not, however, moderate the animosity of the rival business interests toward each other; this is quite as vicious to-day as it was ten years ago.

The position of concrete as a fire-resisting material at the present time may be summarized as follows: It is nowhere under official ban; it is widely employed, both plain and reinforced with steel, for buildings of all kinds—dwellings, churches, work shops and tall office buildings—and it is generally recognized as a good risk by fire insurance companies. This high position is based, so far as questions of fire resistance are concerned, upon the following facts: Numerous full-size floor and partition units have kept their form and strength during and after very severe attacks by fire and water in special test structures. In a comparatively small number of instances such test units have failed. In most cases these failures could be traced to poor design, poor material or poor construction, but in other cases no such cause was traceable and they were reasonably open to the charge of inefficiency of concrete as a fire-resisting material. In addition to fire tests there is the undisputable evidence of concrete buildings and building floors having resisted severe conflagrations with only superficial softening and scarcely any loss of strength.

The arguments that have been brought against these evidences of the efficiency of concrete as a fire-resisting material are substantially as follows: Concrete being a hydrated material, will, if subjected to high temperatures, give up its water of hydration and disintegrate. Practical proof of this theory is deduced from the fact that blocks of concrete if thrown into a furnace ultimately crumble to pieces, and also from such full-size floor test failures as can be accounted for by no other fact than that the concrete lost its strength and integrity under the temperature conditions to which it was subjected. It is hardly necessary to state that these arguments and proofs have not prevailed with engineers in the face of the evidence previously mentioned. This is a fact which no one will be inclined to dispute; nevertheless, the argument is theoretically sound and the proofs cannot be successfully disputed. The question is, do they signify anything important?

To answer this question the facts must first be established. The efficiency of any fireproofing material depends first upon its ability to withstand cracking or disintegration which will destroy its strength and expose to heat the steel it is designed to protect, and second upon its non-conductivity or heat insulating value as a steel protection even when not cracked nor disintegrated. The ability of a material in the first respect may be called its fire resistance, and in the second respect its heat conductivity. What are the fire resistance and heat conductivity of concrete? General evidence that they are satisfactory is found in the experience already quoted, but specific data are needed to establish the facts. These are scarce and such as exist are incomplete, but in default of better evidence they will be quoted so far as they go.

On behalf of the joint committee of the American Society of Civil Engineers, the American Society for Testing Materials, and the American Cement Manufacturers' Association on Concrete and Reinforced Concrete, Prof. Ira H. Woolson, of Columbia University, conducted during the past winter and spring a series of tests on the fire resistance of concrete. The results of these tests were made public by Professor Woolson in a paper read before the American Society for Testing Materials at its annual convention in July. In this paper Professor Woolson also gave the records of the only previous strength tests of cement which had been subjected to high temperatures—the Watertown Arsenal Tests of 1902—and incidentally a single test on the heat conductivity of concrete. The paper was published in full in our issue of July 13, 1905. Independently of the committee named above and following a different method of procedure, a committee of the National Fire Protection Association conducted during the early spring a test to determine the fire resistance and heat conductivity of concrete. The results of these tests were published in a special report, the essential parts of which were printed in our issue of Aug. 3, 1905.

For the details of Professer Woolson's tests the reader must consult the paper mentioned above, but a brief summary of them is as follows: Crushing tests were made on 4-in. cubes and tests for elastic deformation and crushing strength were made on 6 × 6 × 14-in. prisms. The initial tests were made on specimens heated to 500° F. and the temperature was increased 250° F. for each succeeding set up to 2,250° F. for the final set. These were the nominal temperatures attained by the test pieces and for the cubes they were probably the actual temperatures; for the prisms the actual temperatures were probably considerably lower than the nominal ones. The reason for this was that the rate of heating was arbitrarily fixed at 45 minutes to reach the first 500° F. and 30 minutes in each successive 250° F., the maximum heat being held 10 minutes in each case before removing the blocks. At this rate of heating, the final specimens (2,250° F.) remained in the furnace 5 hours and 25 minutes, which was too short a time to heat them to the same temperature throughout, as was shown by a subsequent experiment described as follows in Professor Woolson's paper:

> It was found that by allowing 1 hr. 15 mins. to bring the furnace temperature up to 750° F., and then holding that temperature constant, it required 2 hrs. 40 mins. more for the interior of two different prisms to attain the same temperature. Then raising the furnace temperature to 1,000° in 30 mins., it required 1 hr. 10 mins. more for the prisms to become uniformly heated throughout. The tests were made by imbedding thermo-couples in the middle of the prisms, and connecting them by switch to the same galvanometer on which the couple in the furnace was recording. The concrete on which this test was made was 28 days old. In this instance it required 5 hrs. 35 mins. to obtain a temperature of 1,000° F. through 3 ins. of concrete where the specimen was surrounded by heat on all sides, with no radiation possible.

Incidentally the test just recorded shows the remarkably poor heat conductivity of concrete. Returning to the strength and elasticity tests of the cubes and prisms, it is to be noted, taking the cubes first, that the trap rock concrete began to lose strength at 750° F.; at 1,500° F. the loss was from 25 to 30 per cent., and at 2,250° F. it was from 60 to 75 per cent. The limestone concrete began to lose strength at 500° F.; at 1,500° F. the loss was from 30 to 45 per cent., and at 2,250° F. the cubes crumbled on cooling. The elasticity tests on the prisms showed a very marked decrease in the value of the modulus of elasticity due to heating; this change becomes very apparent even with a temperature of 500° F. and the value gradually decreases with the increase of heat. So much for the results of Professor Woolson's tests.

Turning now to the tests of the committee of the National Fire Protection Association, published in our issue of Aug. 3, 1905, it will be seen that they are of interest chiefly for the evidence they present on the high insulating value of concrete. Briefly described, 8 × 11¾-in. × 6-ft. beams were molded, each imbedding three round steel rods placed respectively 1 in., 2 ins. and [illegible] from the bottom of the beam. Holes were [illegible] in the beams reaching from the top down [illegible] reinforcing rods; in these were placed thermometers. The several beams were laid close together side by side to form the top of a four-walled [illegible] furnace, the temperature inside of which was gradually raised during three hours to between 1,900° and 2,000° F. The results of this test are succinctly stated in the report as follows:

> While there is some difference in the speed with which temperature rose, there is no indication that the difference in the materials composing the concrete was an important factor in the insulating quality of the protection except in the case of the two cinder samples, in both of which the rise in temperature of the rods was quite noticeably slower than in any other sample. There also was a clear indication that the richer mixtures of all materials were slower conductors.
>
> The time required to heat up the rods in all samples which had only 1 in. of concrete covering, as compared with those covered 2 and 3 ins. deep, is the prominent feature of the temperature records and indicates clearly that reinforcing steel members covered to that depth reached a temperature of 770° F., where their strength is impaired to the extent of 25%, very early, well within 1½ hours, or averaging 59 minutes for the 11 samples. Those with 2-in. covering attained the same temperature in an average of 2 hours and 20 minutes, and those protected by 3 ins. of material, in 2½ hours, on an average.
>
> In none of the samples was there any sign of breaking or chipping off of the concrete during the fire, but after being removed it was found that the material had lost practically all its strength to a depth of about 4 ins. from the sides and bottom and that it had softened perceptibly clear to the top. The cement and most of the stone, including both limestone, gravel and granite, seem to have been calcined quite thoroughly at the surface and in a diminishing degree up to about the 4-in. depth. There is no very wide difference in this respect between the various samples, though the beams having the greatest proportion of cement seem to be somewhat more solid than the others.

The close general agreement between the results of the two sets of tests that have been described is the first fact that strikes the observer. Both sets of tests show that concrete furnishes imbedded steel unusually perfect insulation from heat; they also show that concrete heated to temperatures of 2,000° F. and above loses the greater part of its strength. In the way of smaller details they indicate that cinder concrete is a better insulator than stone concrete and that a trap rock concrete is less damaged by heat than a limestone concrete. In respect to heat conductivity these tests bear out all that experience in fire tests and actual fires has led us to conclude, but in respect to fire resistance they give results that do not correspond without conclusions drawn from fire tests and actual fires. It is beyond doubt that concrete construction has gone through severe conflagrations with scarcely any loss of strength and with only superficial softening; how is it, then, that the concrete specimens in these tests showed a material loss strength and general softening and disintegration?

The answer is, of course, that the specimens underwent in the tests more severe conditions than prevail in ordinary building fires or in the customary fire tests. There can be no doubt as to the accuracy of this explanation. In the first place, the ordinary concrete partition, floor or column is more or less protected from the attack of fire by its covering finish of plaster, cinder concrete or other material. These coverings, though normally not regarded as fireproofing, are actually such to a considerable extent; under attack of heat alone they are slow to disintegrate and they are excellent insulators. Again in fire tests and also generally in actual fires the structural concrete is not subject to the attack of equally fierce heat on all sides. The top side of the floor in a test structure gets no direct heat and even in actual fires the floor top usually shows after the fire the wooden nailing strips wholly or partly unconsumed.

The most important difference of all, however, between specimen tests and fire tests of full size units and actual buildings is that the temperatures reached in the latter cases are probably never of an intensity and duration equal to those recorded above. There has been a great deal of misinformation spread about regarding the heat of burning buildings, chiefly by concerns manufacturing and selling fireproofing. By some curious process the belief has grown up that an ordinary building fire represents temperatures of 2,000° F. and above. Doubtless such temperatures are reached, but it is equally certain that they do not endure for any length of

time. Even in a conflagration of the intensity of the Baltimore fire all the evidence indicated that the temperatures reached seldom exceeded 1,800° F., and were often as low as 1,200° F. Moreover, there was probably not a single building in the burned district that remained on fire five hours—the time required according to Professor Woolson's tests to develop a temperature of 1,000° F. through 3 ins. of concrete with 1,000° F. furnace heat—much less that kept a temperature of 1,000° F., or even half that temperature, during such a period. Much more might be said on this point, but the truth of the contention is now so generally recognized by unbiased observers that further discussion seems unnecessary. The truth is that the general temperatures of burning buildings is not high and that such bursts of high temperatures as occur are of short duration.

The preceding statements indicate clearly, it seems to us, why concrete structures have endured actual fires without damage while concrete specimens have failed in high temperature tests, and also why concrete is a good and safe fireproofing material.

LETTERS TO THE EDITOR.

Concerning Solid Wood Slab Roof Construction Without Purlins.

Sir: The letter on "A New Style of Roof" in your issue of Aug. 10, 1905, was read with much interest by the writer. He agrees with the author in every particular excepting that this style of roof construction is neither novel nor original.

One firm at least, T. Pringle & Son, of Montreal, Canada, has used this system for over 12 years in both floors and roofs for factory buildings of every description. This type of construction is also used extensively under the admirable rules of the New England Mutual Factory Association. Several buildings with this type of roof were erected under the writer's supervision long previous to 1903. He also built the mill building in northern New York mentioned by the author.

The appearance of this style of roof or floor can be improved by beading one corner of the lower edge of the planking.

Wherever snow or ice is liable to accumulate, as in saw-tooth roofs, 2 × 4-in. hemlock is hardly heavy enough for 16-ft. spans, and 2 × 5-in. yellow pine should be used for the first six or eight feet from the bottom of each bay.

Any piece of sound lumber, 2 ft. long and over, can be used, and by properly spiking the planking a continuous beam effect is obtained over all trusses, thus producing a very stiff roof. With lumber delivered butted to square ends, waste is practically eliminated.

On flat roofs of buildings designed to drain through interior down-spouts it is possible to form the entire roof in one solid sheet pitching four ways towards the down-spouts, thus doing away with concealed spaces so often found in ordinary construction.

Yours very truly,
Wm. I. Bishop,
Supt. T. A. Gillespie Co.

Whitney, Stanly Co., N. C., Aug. 14, 1905.

What is the Cubical Capacity of a Wheelbarrow?

Sir: How much does a wheelbarrow hold? I am impelled to ask this question because of the methods used on many jobs for measuring the aggregates used in concrete. For example: On a certain concrete job the proportions were 1:3:6 and according to my arithmetic a batch taking two bags of cement would call for 6 cu. ft. of sand and 12 cu. ft. of stone.

The contractor used two bags of cement to three wheelbarrows of sand and six wheelbarrows of stone. If the wheelbarrows each held 2½ ft., as the catalogues tell us they do, then the actual proportions were 2 bags of cement to 7½ cu. ft. of sand and 15 cu. ft. of stone. Contractors, however, say that if a man will not carry 3 ft. to a wheelbarrow load he cannot work for them. From the loads that were carried on this job I believe each was nearer 3 ft. than 2½ ft.

Assuming the load at 3 ft., the proportions for two bags of cement were 9 cu. ft. of sand and 18 cu. ft. of stone. In other words, if we take the catalogue quantities for a wheelbarrow load then the contractor was not using a 1 to 9 mixture, but was using a 1 to 11.25 mixture. If we take the quantities generally carried in wheelbarrows then the contractor was using a 1 to 13.5 mixture.

The engineer in charge did not seem to notice it and the contractor swore that the proportions 1:3:6 meant wheelbarrows and two bags of cement to 3 wheelbarrow loads of sand. The contractor happened to be using a concrete mixer and was using bad language about the maker of the mixer because he said the mixer would hold a batch using two bags of cement in any proportion whereas with his mixture the mixer was constantly spilling out. The mixer happened to be one of a form easily measured and a measurement showed it easily capable of holding 18 cu. ft. As it was spilling out it was plain to see that the wheelbarrow loads must have been fully 3 ft., or a trifle more, for the sand would not much more than fill the voids.

We put a batch through that was carefully measured in boxes instead of wheelbarrows and a two-bag batch did not nearly fill the mixer. I wish to ascertain what the general custom may be among the readers of Engineering News.

Yours truly,
Engineer.

Chicago, Aug. 16, 1905.

A Problem in Detailing Hopper Work.

Sir: Referring to the "Problem in Detailing Hopper Work," in Engineering News of July 20, I wish to suggest shorter methods for obtaining the angle of "flare" χ

Referring to the sketch herewith for the meaning of the symbols, the formula

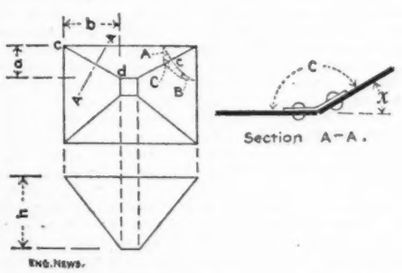
$$\tan \chi = \frac{h\sqrt{a^2+b^2+h^2}}{a\,b}$$

readily reduces to

$$\cos \chi = \cos A \cos B$$

where $\cos A = \frac{a}{\sqrt{a^2+h^2}}$ and $\cos B = \frac{b}{\sqrt{b^2+h^2}}$

As A and B are needed for other purposes, this formula is to be preferred.



Also, a simpler and quicker graphical solution for any skew work may be obtained by use of the principle that all the formulas for the solution of spherical triangles may be reduced to two of the form $\phi_1(x) = \phi_2(y)\ \phi_3(z)$ where ϕ_1, ϕ_2, ϕ_3 are simple trigonometrical functions.

Horace R. Thayer.

South Bethlehem, Pa., July 22, 1905.

Sir: In Engineering News of July 20 a graphical method of determining the angle to which angles or plates at corners of hoppers are to be bent, is given by Mr. Chas. S. Lewis. This problem and others in skew structural work can be easily solved by the rules of Spherical Trigonometry.

$$\text{Given } \tan A = \frac{6\text{ ft. }5\tfrac{1}{2}\text{ ins.}}{4\text{ ft. }6\tfrac{1}{2}\text{ ins.}} = \frac{77.5}{54.125} \quad \therefore A = 55°\ 4'\ 12''$$

$$\text{Given } \tan B = \frac{6\text{ ft. }5\tfrac{1}{2}\text{ ins.}}{6\text{ ft. }4\tfrac{1}{4}\text{ ins.}} = \frac{77.5}{76.25} \quad \therefore B = 45°\ 27'\ 57''$$

Then in spherical triangle A B C

$$\cos C = -\cos A \cos B + \sin A \sin B \cos c.$$

Since $c = 90°$, $\cos c = 0$ and $\cos C = -\cos A \cos B$.

Now $C = 180° - \chi$

$$\therefore \cos \chi = \cos A \cos B$$

$$\log \cos \chi = \log \cos 55°\ 4'\ 12'' + \log \cos 45°\ 27'\ 54''$$

And $\chi = 66°\ 19'$.

Yours truly,
Edw. J. Odlum.

St. Catharines, Ont., July 31, 1905.

Slips and Cracks in a High Irrigation Canal Embankment in British India.

Sir: I have lately had to assume general control of the completion of an irrigation project in which the main channel of 530 cusecs (cu. ft. per sec.—Ed.) capacity is carried for long distances in embankment. One of these banks is nearly a mile in length, the height of the ground surface to bed of channel is in places as much as 40 ft. and to top of bank 48 ft. The inner slopes are 1 to 1 for a total depth of 8 ft. and the outer slopes are 1½ to 1. The top width of the bank is 9 ft. on one side of the channel and 6 ft. on the other. The banks are not puddled. They were constructed in 1-ft. layers by basket coolies and are therefore well compacted by trampling. The material varies but is generally good gravelly earth with or without an admixture of clay.

We recently let water down the channel for a couple of days for a trial. In one place a bank 40 ft. high has subsided and in another place, equally deep, cracks have appeared and there is an ominous bulge near the toe.

Elsewhere we find water oozing out and portions coming away at the toe of the bank. We can see before us a long and troublesome time, and it is a problem how we are to get the bank sufficiently consolidated to safely carry the channel.

Some miles from here there is a 40-ft. bank of similar section, except for 1 to 1 outer slopes, carrying a channel across a depression. It was built Heaven knows when and is now as hard and firm as the surrounding country. The channel was lined with fairly watertight masonry in recent years, but before that if it had any lining at all it could only have been stone slabs laid dry. Somehow or other these old folk got their bank to stand, but their experience is not on record.

It occurs to me that as complete imperviousness cannot be expected at first the man who built these new banks should have provided them with a system of drains to prevent them, if possible, from becoming water-logged and so incapable of carrying their own weight. I do not know whether or not it is the practice to do this; certainly nothing of the kind was tried here.

I shall be thankful if you will direct me to any publication that will help me or if any of your readers who have had similar work to deal with will advise me.

Yours faithfully,
A. H. Bastow, M. C. E.

Trivandrum, British India.

(Possibly some of our readers can direct Mr. Bastow to some helpful literature on this subject or make suggestions based on their own experience.—Ed.)

Credit for the Design and Construction of Two Pacific Coast Reinforced Concrete Chimneys.

Sir: In the issue of Engineering News for July 20, under the head of "The Pacific Coast Engineering Congress," you publish a description of two reinforced concrete chimneys, one for the Portland General Electric Co., and one for the Tacoma Smelting Co. The description states that Mr. George Cotner Mason directed the construction of these chimneys, which is entirely wrong. Mr. Mason and the Concrete Engineering Co., of Portland, Ore., respectively, had nothing to do with designing, calculating or building these chimneys, which were built according to designs made by our Mr. Weber, the inventor and patentee of this system of chimney construction, and we, the Weber Steel-Concrete Co., were builders and supervisors of this work. Mr. Mason and the Concrete Engineering Co., respectively, merely acted as our selling agent, and got a commission for their service from us.

The reason for using T-bars was not that it was too costly or difficult to obtain patent reinforcing bars, but for the simple reason that all of our chimneys are built with a T-bar reinforcement, and that we use T-bars wherever possible on account of their excellent qualities for reinforcing concrete. We could have obtained just as quick and just as cheap, any kind of patent reinforcing bars, but did not use them for the reason stated.

Yours truly, Weber Steel-Concrete Chimney Co.,
Carl Weber, President.

159 La Salle St., Chicago, Ill., July 25, 1905.

(The foregoing letter having been submitted to Mr. Mason he has sent the reply which follows.—Ed.)

Sir: In reply to the letter signed by Mr. Carl Weber of Chicago in reference to the construction of "Two Pacific Coast Reinforced Concrete Chimneys," I beg to state that there seems to be a general misunderstanding.

The writer presented a paper before the "Pacific Coast Engineering Congress," on the "Design and Construction of Reinforced Concrete Chimneys" *in general* and described as notable examples the construction of the two chimneys above mentioned, believing that a specific instance of construction with photographs taken during construction would better present the idea the author wished to convey. The author was not correctly quoted by Mr. Fuller in the report which appeared in Engineering News of July 20, but the distance and consequent delay in making the correction lead the author to let the matter drop.

The author must take exception to one or two statements made by Mr. Weber. The matter of design and type of chimney in each case was very thoroughly discussed by the author and the engineer representing the company for whom the chimney was constructed before Mr. Weber or his company came into the transaction. The contract in each case was let to The Contracting Engineering Co., of which the writer is vice-president, and in each case this company furnished a bond both during construction and covering a maintenance period of five years. In each case the company did a portion of the work and sub-let a portion to the Weber Steel-Concrete Chimney Co. of Chicago. We took a bond from them to cover us for the work they did. As a matter of fact, after making the sub-contract, we talked over the possibility of having the Weber company furnish a bond to the Portland General Electric Co., but this the attorney for the latter company declined to accept as he did not know the Weber company in any legal sense.

The chimney in each case was erected in accordance with the Weber patents and plans and was so stated in a

foot note in the paper read before the society. It did not seem to the author that this was the place to advertise either the Weber Steel-Concrete Chimney Co. or The Contracting-Engineering Co., and each received mention only in a foot note. The plans and strain sheets were checked by the author to see that they met the requirements as to stability covered by our contracts.

The author claimed no originality for the design nor manner of construction, and he hardly thinks Mr. Weber will, either, if he reads some back numbers of the engineering periodicals. The writer, through his company, was most certainly responsible for the design and for the construction and though he might interest the engineers present at the conventions, by telling how these chimneys were built. Very truly yours,

Geo. C. Mason,
of the Contracting-Engineering Co.

Fenton Building, Portland, Ore., Aug 10, 1904.

Low Pulling Portland Cements.

Sir: I note a discussion in your issue of Aug. 3 on Mr. Aikin's paper in reference to low pulling Portland cement. In order that your readers may know the extent of the injustice sometimes done cement manufacturers by specifications containing clauses requiring certain percentages of increase between the 7 and 28-day tests, I submit to you a copy of the tests furnished the manufacturer by the inspector on three cars of Old Dominion Portland cement which was supplied under the specifications quoted further on, and which was rejected for failing to meet the specifications in regard to increase in strength between the 7 and 28-day tests. Tests reported as follows:

Consignment.	1.	2.	3.
Per cent. passing 100 sieve	94.2	93	95.1
Per cent. passing 200 sieve	75.4	75.1	74.9
Set, light wire, in hours	2¼	2¼	3
Set, heavy wire, in hours	4¾	4¾	6
Soundness, air test	O.K.	O.K.	O.K.
Soundness, cold water test	O.K.	O.K.	O.K.
Soundness, boiling water test	O.K.	O.K.	O.K.
Strength, neat, one day, lbs. sq. in.	345	487	416
Strength, neat, 7 days, lbs. sq. in.	790	749	693
Strength, neat, 28 days, lbs. sq. in.	744	772	716
Strength, 1:3 mortar, 7 days, lbs. sq. in.	217	216	228
Strength, 1:3 mortar, 28 days, lbs. sq. in.	299	339	425

The specifications governing cement used on this work required the cement to be sound in hot and cold water, to show a fineness of 92% on a No. 100 sieve and 75% on a No. 200 sieve, not to show initial set under 45 minutes, nor final set over eight hours, and tensile strength as follows:

Neat Cement:	lbs.
After 24 hours in air	200
After one day in air and six days in water	450
After one day in air and 27 days in water	600

The 7-day test shall show an increase of at least 50% in strength over the 1-day test and the 28-day test an increase of at least 25% in strength over the 7-day test.

Mortar Briquettes:	lbs.
After one day in air and six days in water	150
After one day in air and 27 days in water	225

The 28-day test shall show an increase of at least 30% in strength over the 7-day test.

Five briquettes shall be broken for each test and the average of the three highest considered as the strength of the cement.

Notes.—The neat tests are of less value than those of the briquettes made with sand and cement. The fineness of the cement is important, for the finer it is the more sand can be used with it.

You will note by the tests on the three cars given above that the cement met the tests for fineness, soundness and set, and that all the neat tests showed a greater strength at 7 days than was required at 28 days and yet continued to harden up to the 28th day point although not showing the 25% increase. On the other hand, the sand briquettes met the 7-day tests and showed an increase of 33%, 60% and 86%, respectively, yet the cement was rejected. As it was impossible for anybody to furnish a better grade of cement, the manufacturers of Old Dominion Portland cement refused to supply any further cement on the work subject to the interpretation of the specifications by the inspector.

The note at the bottom of the specifications, stating that the neat tests were of less value than the sand tests, would appear to have been placed in the specifications in order that the engineer could use his discretion in accepting the cement if it failed to meet the neat tests after having met the sand tests, yet it did not save the cement from rejection in this particular case. The suggestion made by Mr. F. H. Lewis for specifications to be drawn giving the engineer the option of rejecting cement for failure to show the increase between the 7 and 28-day tests, or not, as he saw fit, would not have helped the matter out in this case.

The writer would like to know from Mr. Aikin whether the Rapid Transit Bureau would reject cement for failing to show 15% increase on the neat briquettes from 7 to 28 days, provided the cement had exceeded this requirement on the sand tests.

Yours very truly,
Wm. G. Hartranft Cement Co.,
Wm. G. Hartranft, Pres.

Fordwick, Va., Aug. 4, 1905.

Sir: In your issue of Aug. 3 I wrote commenting on Mr. Aiken's paper on "Low Pulling Early Stage Portland Cement," and pointed out that material which he rejected was, all things considered, the best material that he had sampled and argued, therefore, that he had failed to prove the correctness of his decisions. In your issue of Aug. 10 Mr. Aiken replies by stating that the good showing of the rejected material loses much of its weight because this cement represented comparatively a very small proportion of the total tested. This view is not reasonable. The exact contrary must be true. Mr. Aiken has conducted the tests for a very large amount of Portland cement and tells us that he adopted a certain criterion for quality. If he rejected but one sample in a hundred this sample becomes the more conspicuous by reason of its isolation; if he rejected but one sample in a thousand this sample is still more conspicuous. It is the worst sample, in his judgment, of a thousand samples submitted for examination. The fact, therefore, that these conspicuous examples of bad product which he thought necessary to reject have proved by his own criterion to be at least as good as any samples submitted, shows conclusively that his basis is at fault.

If a steel manufacturer were to submit a steel bar to Mr. Aiken for approval, the testing machine would show exactly the character of material which the manufacturer had put into his product, but when a cement manufacturer delivers cement powder to the Rapid Transit Commission he delivers stuff which Mr. Aiken will submit both to chemical reaction and to mechanical manipulation before he secures a test piece and, as I pointed out in my previous letter, such test pieces will always show considerable irregularities. I hold, therefore, that there is nothing whatever in the records of cement tests to show that a 15% increase in tensile strength between 7 and 28 days constitute a good cement while a 14% increase would constitute a bad cement. Leaving out of consideration the accidental variation we know that the curve of tensile strength in cements has certain high and low points in it with a tendency to retrograde at long periods. At the time of the construction of the Brooklyn bridge a very valuable series of tensile and compression tests were made. These tests were not made at 7 and 28-day periods, but at intervals of 24 hours from one day on. I regret that I am unable at this writing to lay my hands on the record of these tests, but they showed unmistakably a rise, a fall, and a later rise in tensile strength in each cement submitted whether natural or Portland, these irregularities in the curve of tensile strength being unquestionably due to the process of crystallization which was going on in the cement.

It is evident, therefore, that the tensile strength of different cements at different periods depends entirely upon this hardening or crystallizing action and the relation between the 7 and 28-day tests depends, therefore, on where these high and low points in the tensile curve occur. And this is a matter about which our information is extremely limited. Meantime, however, I am entirely satisfied that neither Mr. Aiken nor any one else is prepared to draw a line between good and bad cements depending upon an increase of 15% between the 7 and 28-day tests, and I hold that Mr. Aiken has demonstrated the correctness of my position by his own results.

Yours truly, F. H. Lewis.

Echols Building, Staunton, Va., Aug. 14, 1905.

The Mosquito Theory and Yellow Fever at New Orleans and Elsewhere.

Sir: In your issue of Aug. 10 you appear to assume that the yellow fever mosquito theory is a fact and not a theory. It may be somewhat out of place for a practical man, given to practical work, to hazard a word on this most important subject, but it would seem that a thing of this kind should be more thoroughly investigated before it is broadly advertised across country as being the only source of infection from this terrible disease. The incalculable and enormous damage that this so-call'ed theory has done to the South during the past month will run into the millions, and when we see thousands of people terrified beyond description at the mere mention of the word "Stegomyia;" when we see gigantic railroad systems tied up, unable to turn a wheel, while commerce and business of every kind is powerless and paralyzed, through fright, and fear, and dread, brought about by this so-called mosquito theory, it might be well to test this theory a little further before preaching it broadcast over the land.

Now is a good time for this test. Bottle up some four or five hundred yellow fever infected mosquitos and ship them to about the latitude of Chicago or Detroit, entirely outside of any region infected, then let several of these mosquito gentlemen subject themselves to their bites. If they have the yellow fever after this, the theory is correct, but if they do not, I should not think there would be any supporting ground for the theory. Take the subjects from men who have never been in a yellow fever infected district. The bare fact that men living in the yellow fever district have yellow fever and are bitten by mosquitos proves nothing whatever, let them be screened ever so tightly.

Isn't it just possible these eminent medical gentlemen have made an error. The writer has known cases in which they have erred. They are not infallible by any means; far from it. In 1878 the yellow fever was attributed to a germ, and several eminent practitioners practically spent their lives trying to run this germ to earth, until at last in despair they jumpel onto that poor, little, cleanly and harmless insect called the mosquito. New Orleans at that time was deluged with carbolic acid to kill the germ, just as it is now being screened to death to keep out the mosquito or keep him in, I don't know which. The task of killing off the Louisiana mosquitos is one to which the digging of the Panama Canal to a sea level is such an infinitesimal undertaking that comparisons become odious, and when you have the spectacle of a health officer telling the people it is a waste of time and energy to clean streets and premises, but to kill mosquitos, well, the least said the better. What do we want to spend millions in sanitation for, if this is not As an ornament or to give employment to the masses?

Do you really believe that Havana got rid of the yellow fever by having the doors and windows of the houses screened? Both that city and Vera Cruz have never had any cessation of mosquitos, although the yellow fever has disappeared from both places. Don't you think the result was accomplished by the efforts of the eminent civil engineers who so thoroughly cleansed the two towns? In the one case, don't you think it was really accomplished by getting rid of all the filth that had accumulated in the harbor of Havana during the past several hundred years, destroying that peculiar condition of vegetation that is most probably productive of yellow fever. Don't you think you give entirely too much honor to these very eminent medical gentlemen, and not quite enough to the poor, hard working civil engineers who really rid the place of its pest, and yet who are too modest to assert themselves.

Since its foundation New Orleans has been covered with surface closets, and its soft, porous soil has become thoroughly saturated with sewage. Now during the past year, the Sewer and Water Commission, the railways, etc., have been turning and digging up this supersaturated soil in an effort to get the city in a thorough sanitary condition, the same as Havana and Vera Cruz. Unfortunate'y they encountered a very bad season this year. First continual rains, next a period of very hot weather, then heavy showers, alternating with heat and so on. Under these circumstances the Old Boy himself would have had fever. Had these gentlemen been blessed with a dry season, I do not believe you would have heard of any yellow fever this year. Now the question arises, Where were the doctors during the winter and spring, the season when mosquitos germinate the least? Why weren't they out killing off the birds instead of waiting for an epidemic to come along?

Clean up New Orleans, as the honorable sewer commission was trying to do, the same as Havana was cleaned, and I dare say you can sit on your front porch and slap mosquitos for forty years without any danger of being contaminated with yellow fever. Gen. Ben. Butler demonstrated this fact very fully during the days of the Civil War, and at the hazard of being called "rash," I will venture to say that if these gentlemen would look into the vegetable kingdom for the causes of yellow fever they would probably be a little more apt to find something interesting than years of useless chasing after germs and other insects.

Give credit where it belongs, to the hard working civil engineer who has cleaned up the cities, and not to some pet hobby of the medicine man, whose exploded theories are as numerous as the sands on the seashore.

Yours very truly,
Pro Bono Publico.

Little Rock, Ark., Aug. 17, 1905.

(We give space to the foregoing letter even though in so doing we are failing to comply with the request made by the writer of it in his letter of transmittal. He there said:

Of all the tiresome things in the world it is this word "Mosquito," and now for you to waste your valuable columns, "Patience ceases, etc., etc." For Heaven's sake have done with it.

Doubtless our correspondent will forgive us for taking space in our "valuable columns" to record his own opinions; and having done that we do not know how we can answer his questions, actual and implied, without taking still more space. But we will endeavor to be brief, referring him for more detail to the extensive literature bearing on the agency of mosquitos in spreading malaria and yellow fever; literature, by the way, which our correspondent apparently has not seen. Our further remarks on this subject may be found on our editorial pages.—Ed.)

EUROPEAN DEATH RATES for 1903, according to the new statistical year book of the German Empire, range from 31 to 14.6 per 1,000 population, as follows: Russia, 31; Hungary, 27; Roumania, 25; Austria and Italy, 22.2; Germany, 20; France, 19.5; Switzerland, 17.6; Belgium, 17.2; Great Britain, 16.4; Holland, 15.6; Sweden, 15.4; Denmark, 14.6.

TUNNEL CONSTRUCTION AND THE SUBSIDENCE OF STREETS IN CHICAGO.

Within the past few months the subsidence or depression of streets in different parts of the city of Chicago has caused some anxiety as to the safety of buildings near these depressions. The cause was widely attributed to the construction of the network of tunnels (6 × 7½ ft. in cross section) built by the Illinois Telephone & Telegraph Co. at a depth of about 30 ft. below the surface, to carry electric cables and a narrow gage transportation system for freight traffic. This tunnel system has been fully described in our columns. A commission of engineers was appointed by the Commissioner of Public Works, Mr. Patterson, to investigate the matter; the members were Mr. E. C. Shankland, M. Am. Soc. C. E.; Mr. John M. Ewen, M. Am. Soc. C. E., and Mr. Louis E. Ritter. The commission presented its report on Aug. 14, and we have been favored with a copy, from which we take the following particulars: In the first place we quote in full that part of the report which deals with the construction work and its relation to the street settlements; this shows these settlements to be due to excavation without the use of air pressure, and acting upon this statement the Commissioner of Public Works has ordered the company to use the pneumatic system for all future work.

The first permits issued by the Commissioner of Public Works required a depth of at least 13 ft. below datum to the top of the crown of the tunnels, or about 27 ft. below street grade. The tunnel in La Salle St., between Madison and Adams Sts., was built at this depth, but we are assured by the City Engineer (and he so stated in his report to the Commissioner of Public Works) that all subsequent work was built with the top of the crown 19 feet below datum.

The tunnels are constructed of concrete, 10 ins. thick on the crown and sides and 13 ins. thick on the bottom. All the main lines, including many of the by-passes and curves at the intersections, were constructed under an air pressure of about 9 lbs. The method of construction was as follows: The bore was dug in the clay for a distance of 20 ft., and about a foot larger all around than the completed tunnel was to be. The 13-in. concrete bottom was then put in place and upon this were placed forms made of 5-in. channel bars in two pieces, and curved to the exact size of the inside of the completed tunnel. Outside of these forms boards 20 ft. long were placed one at a time on each side and the concrete rammed into the space between the boards and the clay. When the crown, forming the key, was reached, boards 3 ft. long were used. It was afterwards found better to build 15-ft. sections instead of 20 ft. The concrete was composed of 1 part Portland cement, 3 parts sand and 5 parts gravel.

Before the outlet to the lake front was built all the clay was hauled away from head houses located in the streets on the curb lines at various places. This hauling was done entirely at night.

The size of the tunnels was fixed in September, 1899, shortly after active work was started. The cross-section determined upon was of the horseshoe form 6 ft. wide by 7 ft. 6 ins. high, inside dimensions. These dimensions were proposed by the company and approved by the city officials. The company proved to the satisfaction of the city authorities that these dimensions were necessary to provide sufficient space for stringing the wires and allowing room for a man to pass between them. This cross-section has been maintained throughout the work. It would seem that experience has shown a way to arrange these wires in a more compact form, and thereby leaves room for the passage of electric locomotives and freight cars. In 1901 the company started to construct the trunk line tunnels 12 ft. 9 ins. wide by 14 ft. high, obtaining a permit for this work from the city engineer, on the plea that as it was impossible to construct manholes in the streets to the tunnels on account of the existing conduits of the Chicago Telephone Co., the Chicago Edison Co. and others, it became necessary to construct these large tunnels in order to introduce therein their large cable reels and transport them through these large tunnels so as to allow the cables to be run into the small tunnels. The action of the city engineer in granting permits for these trunk line tunnels under the 1899 ordinance, was ill-advised; but at the same time we feel that no blame should be attached to him and the criticisms that were made upon him in consequence, we consider unjust. We believe that he was deceived by the pleas which were advanced to show the necessity of the large tunnels.

Work on these large bores was stopped, and although they were afterwards legalized by the ordinance of 1903, no further attempt has been made to build tunnels of this size, so that only about 100 ft. have ever been built.

From an engineering standpoint it is to be regretted that a work of such magnitude should have been prosecuted without having had the basis of a coherent and comprehensive plan. An enterprise of such great importance as this should have been carefully and thoroughly studied out in detail. Before work was begun complete plans and specifications should have been prepared, showing the work contemplated, materials to be used, and the method of construction. In the case of the London subway, a royal commission, which called in the assistance of consulting engineers, has labored for three years and its report is just being published.

When the size of the bores (6 × 7½ ft.) was established, the idea of using the tunnels for freight, in addition to their use as tunnels for wires, was not disclosed by the company nor considered by the city. When the trunk line tunnels were abandoned, probably on account of cost and increased danger of construction, the freight carrying scheme had to be fitted to the existing 6 × 7½ ft. tunnels. On the other hand, the best evidence of the practicability of carrying freight through these smaller tunnels is the fact that many railways entering Chicago have recently become heavily interested in the project. We have not been able to find any authoritative statements concerning capacity of the tunnels to carry the amount of freight claimed; the proper speed for trains; the safe regulation of grade crossings, etc. These questions have as yet not been determined by the company and very probably will not be settled until demonstrated by actual practice. We consider this entire matter should receive the most careful investigation and consideration of competent railway men.

It is a matter of great concern to decide how these tunnels shall be regarded, whether as public highways or as the premises of a private corporation. On the point of view taken by the city will depend the solution of the problems of safeguarding the public or employees of the company against crime, accident, fire, breaking down of power and light plants, etc. There is no provision for emergency exits from the tunnels in case of accident.

The control and supervision by the city of the work of building these tunnels has been lax when compared to similar work done for private individuals or corporations. Ordinary practice demands a definite official plan and specification, and a sufficient force to properly supervise the work at all points and at all times, while in this case there were no definite plans and specifications, and there was but one city representative in the supervision of the entire work. We find the city records of the work very incomplete, for example, we have been unable to find any written specification either for the cement or the concrete. We also find that the city has no official survey showing the exact location of the tunnels. We also find that no attention has been paid to the time clause provided for in the ordinance.

In regard to the effect of these tunnels, on the streets and buildings of Chicago, we would say, the work in the down-town or loop district may be properly divided into two parts. First, the construction of the tunnels built chiefly between 1900 and 1902, which were constructed under air pressure; and, second, the construction of the connections and by-passes from these tunnels which have been built more recently and without air pressure. The commission has been unable to find any evidence of any settlement due to the first part of the work, that is, the building of the main line tunnels under air pressure. Any such settlement would result from two causes: First, the movement of the clay above during the process of excavation or through faulty ramming of the concrete. Such a movement would take place at the time the work was being done or very soon afterwards. The other cause of settlement would be the shrinkage of the clay due to the drawing therefrom of the water. This seepage would be very slow as would also be the resultant settlement. The seepage through the tunnel walls would be apparent of course in the tunnels. As a matter of fact the tunnels were found to be fairly dry. Much of the moisture was found to be due to condensation. We have information from trustworthy sources that the tunnels have at all times been fairly dry, and as a large part of the tunnels in the down-town district have been finished for three years, it would seem that the danger of settlement due to drainage of the clay has little evidence to support it. It is a fact that there are now 17 electrical pumps installed in this tunnel system. The question as to whether the water in the tunnels that is now being pumped out is entirely water of condensation, or seepage, would require a special investigation lasting through several seasons. As an indication of the small amount of water being pumped at present from the tunnels, we are informed that the total bill for Edison current for running all these pumps during the last month was less than $100.

In regard to the settlements due to the second part of the work, that is, the building of connections, by-passes, and new drifts without air pressure, the evidence is at hand and convincing. A number of cases of settlement of streets and buildings were traced to this part of the work and unless some other means of operation are adopted or the greatest care used in construction, there may be further settlements. The commission has not had sufficient time to prepare a plan for minimizing the danger and therefore has no remedy to offer at present.

If the tunnels have been built in accordance with the cross-section submitted and if the work has been properly carried out, we consider their strength to be ample. But the physical condition of an engineering structure is manifested by its plans and specifications, and the evidence that these plans and specifications have been carried out. This evidence is not available in this case, but we would say that the concrete work appears to be of the best material and workmanship and we have no reason to believe it otherwise.

The report of the commission of engineers reviews the somewhat complicated history of the tunnel project, and as this indicates the necessity (and difficulty) of city authorities keeping close watch upon the conduct of such semi-public projects, both in regard to construction and general management, some notes from this may be of interest. No mention is made, however, of the suspicions of graft and illegal procedures which have recently brought the company's affairs before the courts.

In the first place, an ordinance granting the Illinois Telephone & Telegraph Co. the right to operate in all parts of the city (with all wires buried in the district bounded by North Ave., Ashland Ave., 39th St. and Lake Michigan) was introduced in the city council on June 27, 1898, but was not passed until Jan. 23, 1899, and after being vetoed by the mayor was passed in amended form on Feb. 20, 1899. In May, 1899, it was reported that the ordinance had been acquired by a new syndicate, headed by Mr. A. G. Wheeler (the present President), and shortly after this the company secured a lease of the patents controlled by the Strowger Automatic Telephone Exchange Co. On Aug. 4, 1899, the company commenced surveys of the streets in the downtown district, and soon after this the work on the tunnels was started from a shaft at the rear of 170 Madison St. Work was continued until the summer of 1900, and then discontinued until September, 1901, the reason given by the company being that the street lines were incorrectly given by the official city maps, and that it was necessary for the company to make its own surveys before proceeding with the work of tunneling. In September, 1900, the Illinois Telephone & Telegraph Co. filed amended articles with the county recorder extending it corporate powers. Originally these were merely for the "transmission of sounds, signals and intelligence by electricity or otherwise." Under the amended articles power was given "to distribute, convey and deliver telephone messages, telegraph messages, mail, newspapers, and general merchandise, and to convey, distribute, deliver and furnish power, heat, light by steam, water, air, electricity or otherwise, but not by railway." In December, 1901, the Automatic Electric Co. was incorporated (capital, £2,000,000) by parties who had bought the $5,000,000 bond issue of the Illinois Telephone & Telegraph Co., and secured the manufacturing rights in this country of the Strowger Automatic Telephone Co.

On April 7, 1902, when about six miles of tunnel were stated to have been completed, work was stopped by the mayor, Mr. Harrison, who notified Mr. Wheeler, President of the Illinois Telephone & Telegraph Co., that it was evidently the company's purpose to make some other use of the tunnels than that originally intended. A special investigating committee of the city council also demanded a new agreement, making it necessary for the company to secure a new franchise. The committee reported that the work was done in a very satisfactory manner, but that the company had started at two places to build large tunnels 12 ft. 9 ins. wide and 14 ft. high, which work had been stopped by the Commissioner of Public Works. It was recommended that any requests for permits to build tunnels larger than 6 × 7½ ft. should be referred to the city council for action. In June, the judiciary committee took up an ordinance permitting the construction of trunk line tunnels 12¾ × 14 ft. The city's traction engineer, Mr. Bion J. Arnold, reported to the committee that the tunnel was low enough not to interfere with a single-story subway, but that it would have to be lowered if a double-deck subway was decided upon. There was a difference of opinion in the committee as to the legality of the work already done, and the Corporation counsel held that the 6 × 7½ ft. tunnels were illegally constructed. The new ordinance was passed July 15, 1903.

When the forfeiture of the grant was threatened, on the ground that the works executed were not within the meaning of the word "conduit," the company proposed that the city should forego the forfeiture, legalize the tunnels already constructed, authorize the construction of additional

trunk line tunnels and permit the company to carry merchandise. In return for this, the company would build a great system of tunnels for transportation, submit to city regulation as to construction, operation, and rates, and would turn its property over to the city at the end of the original franchise period, Feb. 19, 1929. This was the basis of the ordinance of 1903, which received more attention and consideration by the city, the public and the press than did the original ordinance of 1899, and as a result it was much more carefully drawn. The company has no right to handle passenger business or to lease space in the tunnel for the operation of passenger vehicles. The city has the right at the expiration of 20 years to terminate the grant and to take over the freight business at a price to be determined by appraisal. This applies only to the tunnels and freight business, and not to the telephone business. If, at the expiration of the grant, the city decides not to take over the business, it may invite proposals for the use of the tunnel.

If the city should make a grant to a new corporation, the company is to receive from that corporation a fair cash value of the property taken. Only in case of compulsory purchase before the end of the grant is the city required to make any payment for tunnels. If at the end of the grant the city takes over the property, it is only required to pay for the cars, equipment and fixtures at their fair cash value, being the cost of duplication less depreciation. The compensation to be paid to the city by the company is as follows, payments to be made annually on Jan. 15: for the first ten years, 5% of the gross receipts; for the second ten years, 8%; for the balance of the term, 12%, and for all revenues from the rental of space, 20%.

The later history of the company is taken from a report made by Mr. Evans, of "The Economist," at the request of the engineering commission, and embodied in its own report. The Illinois Tunnel Co. was organized in October, 1903, and at once purchased all the rights and property of the original company, of which it was an extension. It issued stock to the amount of $30,000,000, and executed a mortgage authorizing the issue of bonds for $30,000,000, of which $17,000,000 have been sold. In November, 1904, the Chicago Subway Co. was organized by leading railway interests, and acquired about two-thirds of the capital stock of the Illinois Tunnel Co. and all the stock of the Illinois Telephone Construction Co. New directors were elected to the tunnel company (which continues as the operating company), and the following list of the present directorate indicates the active participation of the railways in this new system of freight handling: A. J. Earling (President, C. M. & St. P. Ry.); E. P. Ripley, (President, A. T. & S. F. Ry.); B. L. Winchell (President, C., R. I. & P. Ry.); J. Kruttschnitt (Vice-President, So. P. Ry. and U. P. Ry.); S. M. Felton (President, C. & A. Ry.); A. C. Bird (Vice-President, Gould Lines); G. B. Harris (President, C. B. & Q. Ry.); F. D. Underwood (President, Erie Ry.); B. Thomas (President, C. & W. I. Ry.); P. A. Valentine (Vice-President, Armour & Co.); A. G. Wheeler (President, Illinois Tunnel Co.). In 1904, property on the west side of the river at Taylor St. was purchased, and has been leased to the Chicago Warehouse & Terminal Co., the stock of which is owned by the tunnel company, and the warehouses and docks will be established and operated by the lessee in the interest of the tunnel company. It is also stated that land at 24th St. and the Chicago River has been taken for a power plant.

The Illinois Telephone Construction Co., owned by the Chicago Subway Co., not only does the construction work for the Illinois Tunnel Co. but expects to contract for the handling of excavations and delivery of building materials for new buildings. In May, 1904, the capitalization of the Chicago Subway Co. consisted of $40,000,000 of stock issued and of a total authorized issue of $50,000,000; the bonded indebtedness consisted of $17,000,000 Illinois Tunnel Co. bonds, and of an authorized issue of $30,000,000. So far as known there has been no increase in the outstanding amount of either stock or bonds. The general impression is that all these various changes of ownership have been accompanied by a very heavy "watering" of the stock, but the report does not enter into this.

As to the present status of the tunnel work and the telephone business, the commission reports as follow:

> On July 31, 1905, there had been completed 173,530 ft. (practically 33 miles) of tunnels, and the work is now being pushed at the rate of about 500 ft. per day. The work done includes connections to some of the new buildings recently erected and now being erected; while connections to some of the old buildings have been started, none have been completed.
>
> The commission is informed by the tunnel company that there are 6,725 telephones in service at the present time: 6,667 main line and 58 extensions. The company now has cables and wires in buildings connecting with the tunnel system for between 25,000 and 30,000 subscribers.

THE U. S. GOVERNMENT CEMENT PLANT AT THE ROOSEVELT DAM, ARIZONA.

One of the most interesting features of the U. S. Reclamation Service's work in constructing the Salt River Reservoir in Arizona is the installation of a complete cement plant for manufacturing the Portland cement to be used in building the great Roosevelt Dam. Some 200,000 barrels of cement will be required for this work and as it is located 40 miles from Globe, Arizona, the nearest railway station, it was found that it would be cheaper to build a cement mill and manufacture the cement from local materials than to purchase the cement and pay the enormous freight rates from the factory to the dam site. Plans for such a plant were, therefore, prepared by Mr. E. Duryee, Cement Chemist for the U. S. Geological Survey, and contracts for the necessary machinery were awarded to the Allis-Chalmers Co., of Milwaukee, Wis. The plant was constructed during the winter of 1904-5.

The accompanying views, Figs. 1 and 2, show the site of the reservoir and dam and the completed cement mill. The latter is a substantial steel frame structure built on a side hill so as to get the advantage of gravity in handling the material through the mill. The mill equipment is of the type usual in plants using rotary kilns and needs only to be cited to be understood. For the preliminary crushing of the limestone there is a Gates No. 4 gyratory crusher, which delivers the crushed limestone to a 30-ft. tapered rock dryer. The clay is crushed in a rotary pot crusher and delivered to a 40-ft. tapered clay dryer. The crushed and dried rock and clay are each elevated in conveyors running side by side, the rock being carried to a ball mill and the clay to an emery mill. From these machines the raw materials are delivered to storage bins, weighed in accurate proportions in automatic weighing machines and delivered to a 5-ft. × 22-ft. Gates tube mill. The raw mix bins are made out of concrete and are cylindrical in shape. The kilns are 7 ft. in diameter at the large end and 70 ft. long, two in number, each carried upon two riding rings. The mix is fed to the upper end of each rotary kiln in a finely powdered state. The fuel used in burning this mix into cement clinker is California crude oil. The clinker discharging from the rotary kilns is delivered to a rotary cooler and the air passing through the cooler, which becomes heated by the time it reaches the upper end, is turned into the suction side of the blower, which supplies the hot blast of air to the kilns and dryers. The clinker leaving the rotary cooler is elevated and delivered to a vertical cooler and discharged from this into a No. 8 Gates ball mill, the product from the ball mill being delivered to 5 ft. × 22 ft. Gates tube mill. Gypsum is added at this point, and the finished cement from the tube mill is delivered to the stock house.

The machinery was placed upon cars in Chicago, in pieces, so that it could be readily taken over the mountain trail in wagons from Globe, the terminus of the railroad, to the dam site. In spite of the amount of machinery furnished, it is stated that nothing important was forgotten or made incorrectly, so that the machines and the plant as a whole, went together perfectly and was ready to operate when set up.

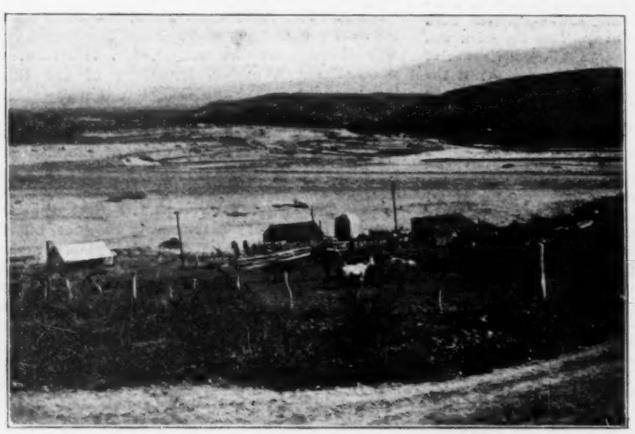


FIG. 1. GENERAL VIEW OF SITES OF SALT RIVER RESERVOIR AND ROOSEVELT DAM, U. S. RECLAMATION SERVICE WORK, ARIZONA.

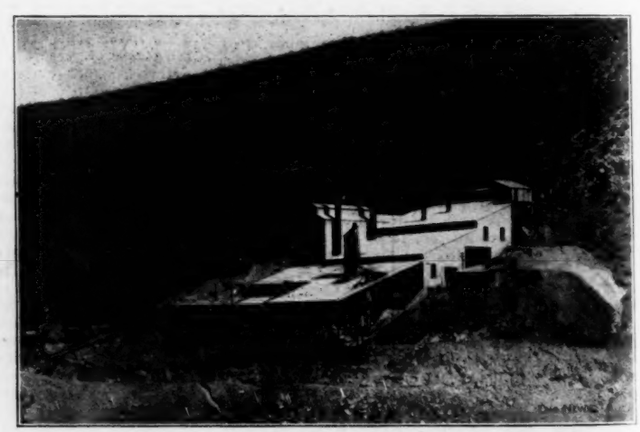


FIG. 2. VIEW OF GOVERNMENT PORTLAND CEMENT PLANT AT ROOSEVELT DAM, ARIZONA.

CAISSON DISEASE was the subject of a suit for damages and a legal decision relating to employers' liability in London recently. A workman had been employed in compressed-air work on the tunnel being built for the Charing Cross, Euston & Hampstead Ry. The pressure in this work is normally 15 lbs., but at times it was increased to 25 lbs. After working in the tunnel for eight months the workman became ill with what was claimed to be caisson disease or "bends." He sued his employers for damages, claiming that the attack was an accident resulting from his employment. The defendants contended that the disease, if caisson disease, was of gradual development and not a sudden happening, hence could not be classed as an accident. The court held that the plaintiff had not suffered from an accident which would entitle him to compensation, and non-suited him.

A PRELIMINARY REPORT ON THE EFFECT OF COMBINED STRESSES ON THE ELASTIC PROPERTIES OF STEEL.*

By Edward L. Hancock.†

For some time engineers and others have been interested in the effect of combined stresses on the materials of construction. Lord Kelvin in the preparation of his article on "Elasticity" for the "Encyclopedia Britannica" made a series of tests made on piano wire. The wire having sufficient weight to hold it straight while suspended was subjected to a torque at the bottom; when an additional weight was added it was found that the elastic limit of the wire in torsion was lowered. From these tests it seemed possible that the same thing would be true in the case of compression torsion (loaded column), although no tests of this kind were made. Mr. J. J. Guest, in England (see Proc. Physical Soc. of London, September, 1900), carried out a series of tests to obtain the effect of combined stresses on ductile materials, the materials used in the tests being wrought iron, mild steel, copper and brass. The results of these tests also lead to the same conclusion, that the elastic properties are lowered when the materials are subjected to combined stresses.

The slight knowledge on this subject and the entire absence of any information available for engineers have inspired the writer to carry out a series of investigations that should give some information immediately available for practical work. The series contemplated includes the following:

(a) Tests of steel and iron solid rounds and hollow tubes in tension while under torsion.

(b) Tests of steel and iron solid rounds and hollow tubes in torsion while under tension.

(c) Tests of steel and iron solid rounds and hollow tubes with increasing tension and torsion.

(d) Tests of steel and iron solid rounds and hollow tubes in compression while under torsion.

Thus far only a part of series (a), on solid steel rounds, has been carried out, and the results given in this report are taken from these tests.

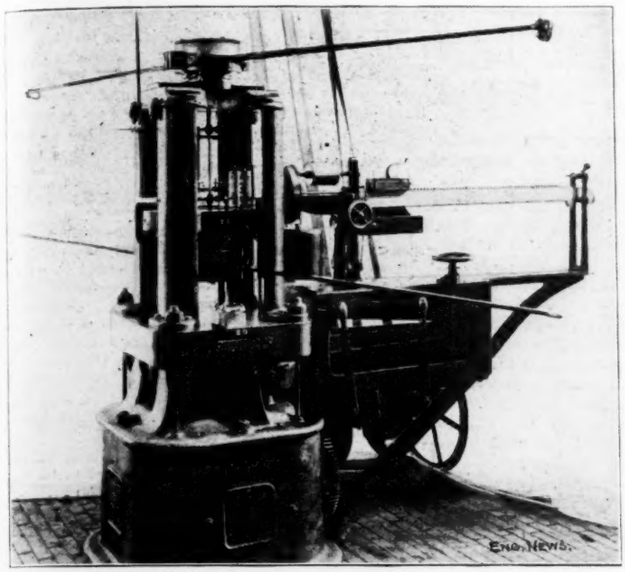


FIG. 1. VIEW OF 100,000-LB. TESTING MACHINE FITTED UP FOR TESTS UNDER COMBINED TENSILE AND TORSIONAL STRESSES.

APPARATUS FOR TESTING.—The difficulty of making tests of materials under combined stresses lies principally in the fact that no machines are available for such tests. The apparatus used in the tests under consideration is shown in Fig. 1. It consists of two specially constructed heads fitted to an ordinary 100,000-lb tension testing machine. Each of these heads consist of a flat cast-iron base fitting into the slot in the head of the testing machine provided for the insertion of the wedges, as ordinarily used. The outer side of this casting is finished to provide for three concentric rows of hardened steel balls, which rest upon a steel plate and are covered by another steel plate. The outer side of this latter plate is a spherical cup. This receives the large casting, or chuck, carrying the wedges and arms. The spherical bearing allows the specimen to "line up" properly. The construction of the heads is seen in Fig. 2. Each head is provided with two arms 5 ft. long, the lower arms having steel rollers that bear against stationary knife-edges, while the upper arms are provided with knife-edges and stirrups to which the cords carrying the loads are attached.

In order that the loads in torsion might be applied, two frames were constructed to support the stationary knife-edges for the lower arms and also to carry bicycle wheels over which passed the cords that were attached to the upper arms. These wheels were so located that the cord was perpendicular to the arm and on the same horizontal. To the other end of the cord was suspended a small bucket as a receptacle for the sand used in loading. The buckets were counterbalanced by a weight attached to a cord running back over the wheel.

METHOD OF HOLDING THE SPECIMEN.—The large casting of each head carries three lugs provided with slots for the insertion of the wedges. These lugs are so

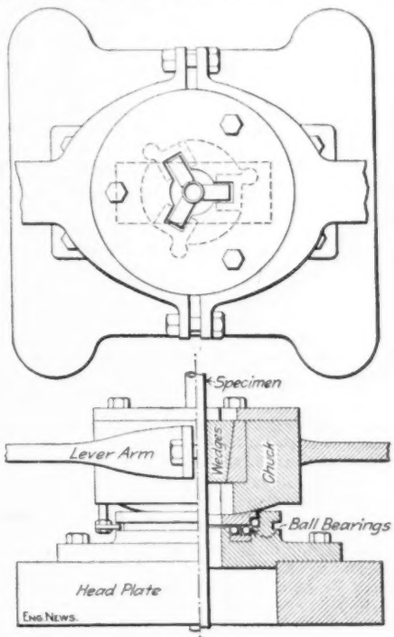


Fig. 2. Plan and Section of Ball-Bearing Torsion Head Used in Tests Under Combined Tensile and Torsional Stresses.

arranged that when a torsion load is applied the wedges tend to grip the specimen, due to the swinging out of the lugs (see Fig. 2). This method of holding allows the use of specimens of different diameter and admits of easy manipulation.

APPLICATION OF LOAD IN TORSION.—The desired load in torsion was given by allowing a known quantity of fine dry sand to run uniformly into the buckets attached to the cords. This load was transmitted to the arms and a part of it to the specimen (a part was taken up by the friction of the bearings). The use of sand gave a uniform application of load and was very satisfactory.

MEASUREMENT OF TWIST AND ELONGATION.—The amount of twist was measured by means of an ordinary troptometer on a 10-in. gage length, and the elon-

*A paper presented before the American Society for Testing Materials, at Atlantic City, N. J., June, 1905.

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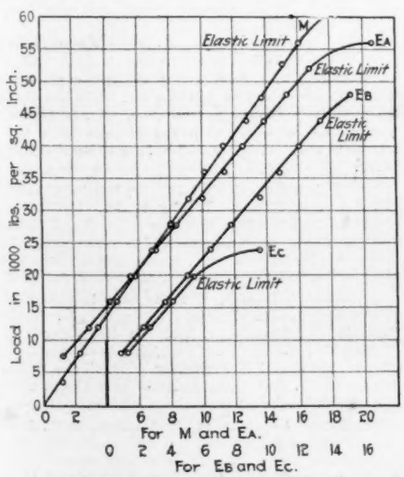


Fig. 3. Tensile Stress-Strain Curves of Nickel Steel.

M = Plain Tensile Test (average of two tests).

E_A = Tensile Test to Elastic Limit while under Torsion to one-third the elastic limit in extreme fibers.

E_B = Tensile Test to Elastic Limit while under Torsion to two-thirds the elastic limit in extreme fibers.

E_C = Tensile Test to Elastic Limit while under Torsion to elastic limit in extreme fibers.

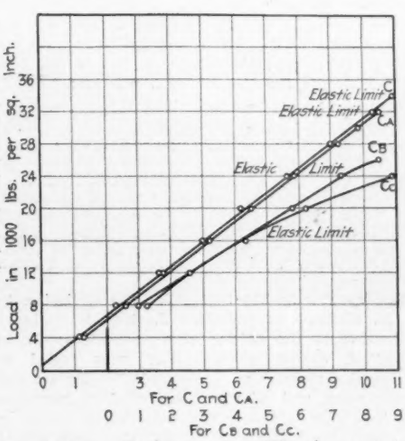


Fig. 4. Tensile Stress-Strain Curves of Carbon Steel.

C = Plain Tensile Test (average of two tests).

C_A = Tensile Test to Elastic Limit while under Torsion to one-third the elastic limit in extreme fibers.

C_B = Tensile Test to Elastic Limit while under Torsion to two-thirds the elastic limit in extreme fibers.

C_C = Tensile Test to Elastic Limit while under Torsion to elastic limit in extreme fibers.

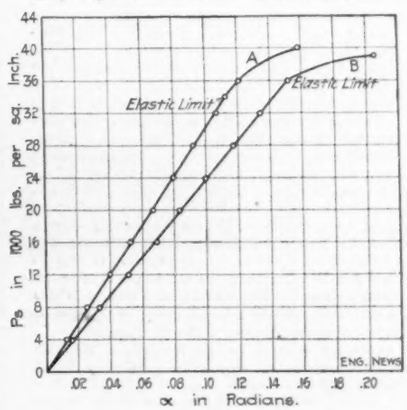


Fig. 5. Torsional Stress-Strain Curves of Nickel Steel.

B.—Plain Torsion Test (average of two tests).

A.—Torsion Test to Elastic Limit while under Tension of 4,000 lbs. per sq. in. (average of two tests).

FIGS. 3 TO 5. STRESS-STRAIN CURVES OF STEEL UNDER COMBINED TENSILE AND TORSIONAL STRESSES.

Test-pieces 0.50-in. diameter; torsional deformation measured on 10-in. original length; tensile elongation measured on 8-in. original length.

gations were measured by a Yale-Riehle extensometer on an 8-in. gage length. The extensometer was placed symmetrically between the arms of the troptometer. This means of measuring deformations was entirely satisfactory for the series of tests made, but will have to be changed somewhat for the series (c).

GENERAL METHOD OF TESTING.—The tests of series (a) already made consist of two sub-series, (E) and (C), the former on 3% nickel steel and the latter on carbon steel, both being supplied through the courtesy of the Carnegie Steel Co. The metals used had the following composition:

	Phos.	Mn.	Silicon.	Nickel	Carbon.
Nickel steel..	0.019	0.65	0.022	3.02	0.25%
Carbon steel..	0.030	0.55	0.024	0.00	0.24%

In each series three pieces were used. These were about 5 ft. long and 0.85 in. in diameter and turned down for a length of 11 ins. at the center to a diameter of 0.50 in. In each case a tension load of 4,000 lbs. per sq. in. was applied to hold the specimen in place and cause the wedges to grip properly. One specimen in each series, (E_A) and (C_A), was tested in torsion to one-third the elastic limit by application of sand, troptometer readings being taken. The specimen while held with this load in torsion was tested in tension to the elastic limit. A second specimen in each series, (E_B) and (C_A), was tested in torsion in the same way to two-thirds the elastic limit, and while under this load in torsion was tested in tension to the elastic limit. The third specimen of each series, (E_C) and (C_C), was tested in torsion to the elastic limit, and while under this load was tested in tension to the elastic limit.

FRICTION OF THE HEADS AND ROLLERS.—The friction of the rollers attached to the lower arms and bearing on the stationary knife-edges was measured and found to be negligible. That is, the amount of upward pressure due to this friction (constant for these tests) was less than could be read on the beam of the 100,000-lb Olsen testing machine.

The effective moment due to the friction of the ball-bearings and bicycle wheels was determined for the tension load of 800 lbs. (corresponding to a load of 4,000 lbs. per sq. in.), this being the constant load in tension used while the torsion tests were being made. The tests were made by placing the heads on the platform of the machine, back to back, and compressing them with a load of 800 lbs. and determining the weight of sand necessary to move the arms. The average of a number of tests gave 16.42 inch-pounds as the effective twisting moment due to the friction of the heads and bicycle wheels. This moment was deduced in making calculations.

It is seen from the above that the effect of friction in the tests already made has been accounted for in a definite way, making the tests satisfactory. The plan of work includes the determination of a friction curve for the apparatus. This curve will show the twisting moment lost due to friction for any safe load in tension.

RESULTS OF TESTS.—Fig. 3 gives a stress-strain diagram of nickel steel in tension. The curve M is a curve from the average of two simple tension tests of the material and shows the elastic limit to be 56,000 lbs. per sq. in. The three curves E represent the behavior of the material in tension while held in torsion: E_A held in torsion at one-third the elastic limit, E_B held in torsion at two thirds the elastic limit, and E_C held in torsion at the elastic limit. The curves show a lowering of the elastic limit in tension: a lowering of about 7% in the case of E_A, about 21% in the case of E_B, and about 63% in the case of E_C. When the series of tests contemplated has been completed it is hoped that the law of the lowering of the elastic limit may be determined. The modulus of elasticity in tension has also been lowered.

Fig. 4 shows the stress-strain diagram of carbon steel in tension. The curve C represents the average of two simple tension tests of the material, showing an elastic limit of 34,000 lbs. per sq. in. The curve C_A shows the result of a tension test made while the specimen was held at one-third its elastic limit in torsion; C_B while held in torsion at two-thirds its elastic limit, and C_C while held in torsion at its elastic limit. These curves also show a lowering of the elastic limit; a lowering of about 6%, 30% and 54% for C_A, C_B and C_C, respectively. It will be noticed that this is not exactly the same rate of lowering as that given by Fig. 3. The modulus of elasticity in this case does not seem changed in the case of C_A, but is lowered considerably in the case of C_B and C_C.

In all cases the increase in the troptometer readings while the loads in tension were being applied—and this notwithstanding the increased friction of the heads—showed a decided weakening of the material in torsion due to the combined stresses. However, sufficient data have not been taken to give a satisfactory report on this point.

Fig. 5 shows two torsion curves, A and B, the former representing an average of two tests of the material made while the specimen was under a tensile load of 4,000 lbs. per sq. in., and the latter an average of two simple torsion tests of the same material. The curves show the expected lower elastic limit in the case of the specimens subjected to combined stresses. In the case of this plate the ordinates represent the shearing stress on the outer fiber and the abscissae the angle of twist measured at the center of the specimen.

When the tests have been more completely worked out it is planned to compare the values obtained from the tests under combined stresses with those obtained by computing the formulae:

$$q_s = \tfrac{1}{2}\,(p^2 + 4\,p_s^2)^{1/2}$$
$$q = \tfrac{1}{2}\,[p + (p^2 + 4\,p_s^2)^{1/2}]$$

where p is the load in pounds per square inch in simple tension, p_s the shear on the outer fiber in simple torsion, and q and q_s the normal and shearing stresses on an internal plane of the material.

In conclusion, the writer wishes to acknowledge the efficient work of several senior students who made it possible to carry out the tests that have been made: Mr. Carlos Robles Gil, Mr. C. E. Shearer, Mr. F. O. Blair, Mr. W. R. Wheeler, Mr. J. H. Lambert and Mr. J. W. Krull; and to acknowledge particularly the helpful suggestions of Professor W. K. Hatt in charge of the Laboratory for Testing Materials.

NAVAL BOARD OF INQUIRY REPORT ON "BENNINGTON" BOILER EXPLOSION.

The disastrous boiler explosion on the U. S. gunboat "Bennington" on July 21 in San Diego harbor, California, was submitted to a naval court of inquiry for investigation. The board has now made report to the Navy Department of its findings. The document recites the conditions of the accident and indicates the persons to blame.

The boilers of the "Bennington" were, according to the report "in fair condition and efficient, considering their age (about fourteen years) and the use to which they had been subjected."

On the day of the accident, July 21, 1905, the boilers were filled and started, and soon afterward a fireman was sent up to close an air-cock on the boiler which later exploded. The court is of the opinion that he closed the valve between the boiler and the steam-gage. The furnaces were then fired hard for about an hour. At 10.30 the boiler in question developed a slight leak. Shortly afterward the boiler exploded. The middle or lowest corrugated furnace collapsed. This threw the boiler over onto the rear boiler, which then also exploded.

The subjects of steam pressure and condition of the safety valves are thus reviewed:

No one seems to have noticed any escape of steam from the safety valves of any of the boilers, and no one can state that any of the safety valves blew off at any time that morning. We can find no record of the safety valve of boiler B having been overhauled since July, 1904, nor any positive evidence of it having been done, though orders had been given for this to be done in March, 1905; there is no record of the sentinel valves having been overhauled since July, 1904. The safety valves were set at 145 lbs.; but en route from Honolulu to this port orders were given to carry the steam pressure at from 130 to 135 lbs., not to exceed the latter, but the safety valves were not changed; this order had been clearly understood. The hand gear for lifting the safety valves was not in working order, and there is no record nor direct evidence that the safety valves had been tested in accordance with the navy regulations.

The court's opinion states that not only was the safety-valve of the boiler first to explode set for a higher pressure than ordered, but it failed to lift at the pressure for which it was set:

The court is of the opinion that the explosion was caused by excessive pressure in boiler B, which came about, first, by shutting the valve connecting the boiler with the steam gage, instead of the valve on the aircock alone, as was intended, so that the steam gage did not indicate the pressure in the boiler; second, by unusual and heavy firing in the boiler to get up a pressure which the gage failed to show; third, by the failure of the sentinel and safety valves to lift at the pressure for which they were set, and the pressure increased without relief until it was beyond the strength of the boiler, which gave way in its weakest part, afterward found to be the corrugated flue of No. 2, the lowest, or middle, furnace, which collapsed.

The court attaches blame for the explosion to D. N. Holland, second-class fireman, who closed the valve in the safety-valve connection; F. de Courtani, acting water tender, who failed to notice the absence of pressure-indication on the steam-gage, and who further failed to interpret the leak shortly before the explosion as evidence of excessive pressure; E. B. Ferguson, chief machinist's mate, on watch, in charge of engine and fire rooms, who failed to detect these omissions, and C. T. Wade, ensign, in charge of the engineering department of the vessel, who failed to have the safety-valves and sentinel valves overhauled and tested at proper periods. The first-named three were killed in the accident. Ensign Wade, it is recommended, should be subjected to trial before a general court martial.

The court reports in regard to the furnace which failed, that

After an examination of the collapsed furnace flue and from physical tests that we have had made, the material of this furnace flue was of good quality.

The court also reports that the ship is practically uninjured, except in and about the engine and boiler rooms.

A ROCK SLIDE IN A QUARRY at Ormrod, Pa., on Aug. 16, buried 30 men, of whom 20 were killed. The quarry is owned by the Lehigh Portland Cement Co. The pit was fully 100 ft. deep, and it is stated that the recent heavy rains are responsible for the slide of earth and rock.

AN OPEN DRAWBRIDGE caused a very serious railway accident near Norfolk, Va., on Aug. 17. An excursion train from Kinston, N. C., to Norfolk approached the open draw at moderate speed, but could not be stopped in time. The engine and two of the cars went into the river, most of the occupants of the first two coaches were killed outright or drowned. The killed will probably number nearly fifty, but up to the present only some twenty have been recovered.

A TROLLEY-CAR CROSSING ACCIDENT at Butte, Mont., on the evening of Aug. 20 caused the death of eight persons. A crowded trolley car returning to the city from a pleasure resort failed to stop at a railway crossing and when just on the track was truck by a slowly-moving switching train. The killed were passengers on the car.

PERSONALS.

Mr. A. C. Butterworth, Inspector of Maintenance of Way of the Wabash Ry., has been appointed Assistant Engineer, with headquarters at Chicago.

Mr. W. A. Doane, formerly City Engineer of Meadville, Pa., has been appointed Division Engineer of the South & Western Ry., with headquarters at Bristol, Va.

Mr. Wilbur S. Hanna, Assistant Engineer in the U. S. Geological Survey has been instructed to report at the Washington Office for work in the Hydrographic Division.

Mr. Myron S. Falk, Assoc. M. Am. Soc. C. E., of 60 Wall St., New York, has been appointed Consulting Engineer to the New York State Water Supply Commission.

Mr. Sherman Smith, heretofore in the Chief Engineer's office of the Union Pacific R. R., at Omaha, Neb., has been transferred to the Division Engineer's office at Denver, Colo.

Mr. William M. Belding, for several years a Superintendent of Construction with George B. Swift Co., contractors, of Chicago, Ill., has been appointed Superintendent of building construction on the Panama Canal.

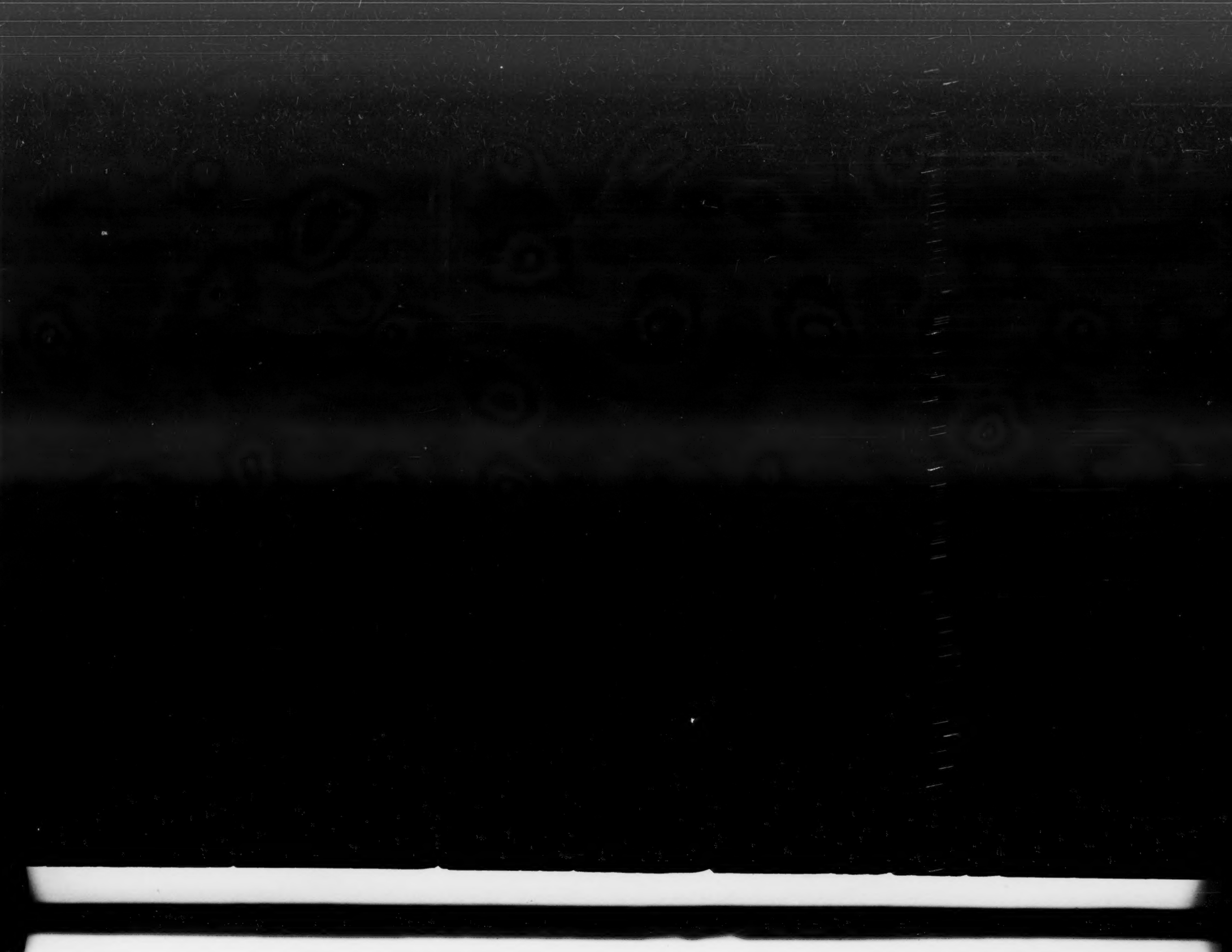
Mr. James W. Sussex has been appointed Assistant Engineer in the U. S. Reclamation Service and will report for duty at Casper, Wyo. Mr. Sussex is a graduate of the Civil Engineering Department of the University of Illinois.

Mr. L. P. Atwood, Engineer of Maintenance of Way of the Chicago, Peoria & St. Louis Ry., has been appointed Superintendent of the Litchfield & Madison Ry., which is owned by the former line. He has his headquarters at Edwardsville, Ill.

Mr. Robert R. Livingston has accepted a position with the Engineering Co. of America, and will make his headquarters at 74 Broadway, New York. Mr. Livingston formerly was connected with the Allis-Chalmers Co. and recently with W. S. Barstow in electrical engineering work.

Mr. T. A. Jones, of Norfolk, Va., has been selected to fill the vacancy in the faculty of the Virginia Military Institute, occasioned by the resignation of Col. Robert A. Marr, Professor of Engineering. Mr. Jones was graduated from the Institute in 1898, and at present is connected with the Seaboard Air Line Ry., as an Assistant Engineer.

Mr. Wm. N. Stevens, who has been in charge of the design and erection of power stations, etc., for the Edison Electric Illuminating Co. and the Interborough Rapid Transit Co., both of New York, has been appointed Assistant Mechanical Engineer for J. G. White & Co., 43 Exchange Pl., New York, and will have charge of drafting and detail design.

Mr. Walter E. Harrington, M. Am. Inst. E. E., formerly Vice-President and General Manager of the New York & Philadelphia Co., has become associated with J. G. White & Co. as Operating Manager. In this capacity Mr. Harrington will supervise all of the railway, electric lighting, gas and other properties operated by J. G. White & Co. He will make his headquarters at the New York office of the company, 43 Exchange Pl.

Mr. Jacob Kraus, who was nominated by the Netherlands Government [illegible] has been appointed Minister of [illegible] Industry, in the recently [illegible] As a consequence Mr. Jan [illegible] appointed as a member [illegible] Engineers to succeed Mr. Kraus. Mr. Verhagen, who [illegible] 1900, has had charge of the supervision of [illegible] rivers of the Netherlands.